Pre-roman iron age metalworking tools from England and Wales: their use, technology, and archaeological context

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Part i (ii)

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ABSTRACT

Pre-Roman Iron Age Metalworking Tools from England and Wales: their Use, Technology, and Archaeological Context

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Archaeological evidence suggests that a wide range of metalworking techniques was employed during the Iron Age in Britain. This study examines the metalworking tools which have survived, principally those made of iron, and includes hearth implements, and tools for forming, decorating, and finishing metals.

The ferrous metalworking tools are analysed in terms of typology and technology. Their occurrence in different types of archaeological contexts is examined, in particular relationships with metalworking residues. Functional and social use of the tools is discussed.

Forty-one edge tools and six hearth implements are examined by metallography. The results are discussed according to tool type, and are further assessed by comparison with other categories of Iron Age ferrous artifacts (from published sources), and with metalworking tools of similar date from the Continent.

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Declaration

No part of this thesis has been previously submitted for a degree at any University

Statement of copyright

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INTRODUCTION

Metalworking during the Pre-Roman Iron Age in Britain encompassed the collecting and smelting of ores, the refining of metals, and the manufacture of artifacts principally by wrought techniques or the casting of non-ferrous metals. This study examines the tools which were used for the working of metals, in particular those used for wrought techniques since smelting and casting processes did not involve tools to work the metal directly.

The techniques and equipment for non-ferrous metal preparation and casting, and other aspects of these processes during the British Iron Age have been studied by Tylecote (e.g. 1962; 1976; 1982; 1987), Coghlan (1975), Spratling (1979), Foster (1980), Howard (1980; 1983), Bayley (e.g. 1984a; 1985a; 1988), Northover (e.g. 1984b; 1985; 1988), and others. Wrought non-ferrous wrought artifacts have been analysed mainly in terms of stylistic and chronological affinities (e.g. Savory 1964; Spratling 1970a; 1970b; 1970c; 1972; Frey with Megaw 1976; Jope 1976; Stead 1985a), though include technological analysis from tool marks (e.g. Lowery *et al.* 1971; 1976).

Studies of ironworking processes have tended to concentrate on smelting, or the interpretation of smithing procedures through metallographic examination. The techniques of iron-smithing have received far less attention, though notable works are Saunders (1977), and others which encompass British Iron Age material (Tylecote 1962; 1982; Manning 1969; 1985; Scott 1974a; Coghlan 1977; McDonnell 1986a).

Archaeological evidence suggests that metals were worked primarily with ferrous tools at least during the later Iron Age, and occasionally with tools made from other materials. This is supported by analogy with agricultural implements (e.g. Rees 1979), tools for other crafts (e.g. Bulleid and Gray 1917; Goodman 1964; Sellwood 1984), and continental evidence (e.g. Ohlhaver 1939; Jacobi 1974).

The scarcity of metalworking tools from the Iron Age in Britain has been commented upon on several occasions (e.g. Spratling 1970a, 190-1; 1972, 348; Megaw 1985, 173-4; Stead 1985b, 12). Saunders notes that the blacksmith's tools which are known 'would not stock a single forge' (Saunders 1977, 17), and that the knowledge of tools is often inferred from the manufacturing techniques which themselves are assumed from artifacts (Saunders 1977, 13). Manning has pointed out:

> 'without a wider range of tools than has survived the existing ironwork could not have been made' (Manning 1981, 52).

Manning attributes the low number of known tools to the comparative rarity of iron generally from Iron Age occupation sites, and to the lack of aesthetic appeal of iron as a category of material for study (Manning 1969, 16). X-radiographic units have been more readily available recently for the screening of ironwork, and indeed X-radiography is now considered to be the principal aid to the study of ironwork (Hunter 1988). Nevertheless, priority is still often given to the easily identifiable, complete, complex, or decorated artifacts. Assemblages of ironwork from earlier excavations have seldom been reassessed.

The apparently limited range of known Iron Age metalworking tools (Manning 1969; 1976) is shown in surveys of techniques and tools (Coghlan 1977, 67-79; Saunders 1977; Stead 1985b, 8-14), and tools from specific groups (Rodwell 1976; Manning 1980). Continental evidence suggests that a variety of iron tools were employed from the late Hallstatt period (Ohlhaver 1939; Jacobsthal 1944; Pleiner 1962; 1980; Spehr 1975; Bouzek 1989) and a wide range of tools is known from the latter part of the Iron Age (e.g. Déchelette 1914; Reinach 1917; Ohlhaver 1939; Pleiner 1962; 1980; Jacobi 1974; Teodor 1980).

Both Manning and Saunders note that the majority of 'major' Iron Age ferrous artifacts from Britain are from graves, hoards, or ritual deposits (Manning 1969, 19; Saunders 1977, 18). Tools are primarily utilitarian, and those which have survived may therefore be recognisable in archaeological contexts with metalworking connections (cf. Megaw 1972; 1985), and possibly also in other archaeological contexts related to their manufacture, storage, or social use.

Although the potential technological benefits of iron were probably not motivating factors in its adoption and early use (Scott 1978; Champion 1980; Barrett 1989; Thomas 1989), it is often assumed that by the later Iron Age the benefits would have been realised and improvements made - at least in utilitarian artifacts (e.g. Coghlan

1977; Pleiner 1980; Alexander 1981). Since metalworkers were probably one of the few groups of craft specialists to make their own ferrous tools, presumably they would have applied their knowledge to improve the properties of the tools. Thus, it seems possible that technological developments, if any, may be demonstrated in metalworking tools.

The present study examines the three aspects of pre-Roman Iron Age metalworking tools outlined above: the range of tools, their archaeological occurrence and use, and their technology. The aims are to identify the basic range and the individual types of tools, and to characterise those tools as fully as possible. Chronological and technological trends are examined, and also the occurrence of the tools in different types of archaeological context. Functional and social use of the tools are investigated.

The catalogue of tools (Appendix A) comprises solely ferrous tools, though tools and implements made from other materials are noted elsewhere. Included are hearth implements, and tools for forming, finishing, and decorating metalwork.

The iron tools, which are the prime subject of this study, were probably used for working ferrous and non-ferrous metals in a variety of techniques and under different working conditions. Chapter 1 examines evidence for the metals and the principal manufacturing processes employed during the Iron Age, the characteristics and properties of the metals used, and the qualities which may have been required of the tools to work these metals.

Other technological factors involved in metalworking, together with social aspects, are examined in Chapter 2. The approaches which are used to study metalworking in general are outlined, and more specifically, methods applied to ironworking and iron artifacts. The identification and characterisation of tools for working any material may be complicated by condition, wear, modification, possible differences in manner of use, and other factors. These, and other problems related to the characterisation of tools, and in particular iron tools, are discussed in Chapter 2.4. The analytical procedure of the present study is given in Chapter 2.5.

In Chapter 3, the tools are discussed in terms of typology, technology, and likely purpose and use. Chronology, and contexts and associations which are possibly relevant both to functional and social use are summarised. In order to characterise the tools in terms of their metal structure and method of manufacture, a number of the tools have been examined by metallography (Appendix B). The results are summarised in Chapter 3 according to each category of tool, and in Chapter 4 the interpretations are discussed in more general terms. Their metallurgical significance is assessed by comparison (from published sources) with other categories of Iron Age ferrous artifacts from Britain, and with metalworking tools of similar date from the Continent.

In Chapter 5, the occurrence of the metalworking tools in different types of archaeological contexts is examined, in particular relationships with metalworking residues, and the evidence for functional and social use is discussed.

The principal findings of the study are summarised and discussed further in Chapter 6.

The geographic area of study is limited to England and Wales though examples of tools from outside this area are occasionally cited. To save repetition, county names are given only at the first mention of a site unless ambiguity may arise. When not otherwise specified, references to the sites with metalworking tools are given in Appendix C, which serves also as a concordance for Appendices A and B.

The chronological limits are from the earliest use of iron in Britain, which accords generally with ceramic dates for the earliest Iron Age occupation (e.g. Cunliffe 1984a) from the eighth or seventh centuries BC, until the Roman period *c.* mid-first century AD. Between these limits, the term 'earlier Iron Age' is applied in this study for the period to around the fourth century BC, and the 'later Iron Age' thereafter.

The term 'iron' is used generically to cover ferrous metals derived from the bloomery process unless the use of steel (carburized iron) is specifically intended. Non-ferrous metals include copper, tin, lead, silver, gold, and alloys of these metals. Where a specific metal or alloy is referred to, or analysis has been carried out, this is stated. For consistency, therefore, the term 'bronze' is used only for copper-tin alloys where analysed, despite the likelihood that the earlier alloys were bronze (cf. Bayley 1988). However, the terms 'bronzeworking' and 'bronzeworker' are used in the broader sense for the working and worker respectively of copper-based alloys on the assumption that selected analyses of copper alloys from specific assemblages reflect the typical range of metals employed at those sites. Furthermore, 'ironworking', 'non-ferrous metal working', and 'copper alloy working' are used as convenient terms to encompass smelting and manufacture where the nature of the evidence is unclear.

The terms 'forging' and 'smithing' and their derivations are used synonymously, as also are the terms 'casting' and 'founding', which in their respective contexts refer to the basic forming or shaping of metal artifacts.

CHAPTER 1

METALS AND METALWORKING IN THE IRON AGE

1.1. Introduction

The selection and use of metals during the Iron Age probably depended on a combination of factors including availability, working properties during manufacture, physical properties required in the finished product, as well as economic, political, and social reasons. This chapter examines the evidence of metalworking during the Iron Age, the metals and alloys which are known to have been used, and their characteristics and properties.

The principal manufacturing processes discussed are iron-smithing, and the wrought working and casting of non-ferrous metals. The making of coins and composite metal artifacts are also included since these employed slightly different techniques. The present study is concerned principally with iron tools; this chapter therefore concentrates on the properties and characteristics of iron, and of the iron tools. Those ferrous processes which have a direct bearing on the metallurgical interpretation of the tools are dealt with in greater depth in Chapter 4.

The sources and extraction of the metals and the individual metalworking techniques have been fully described elsewhere (e.g. Coghlan 1975; 1977; Tylecote 1986), and are not reiterated here unless relevant to the possible occurrence of tools, or of their use. The waste materials from the various processes are described since these are the key indicators of metalworking activity, and the association of debris with tools assists in reconstructing the techniques employed, and in identification of the function of the tools.

Each of the main metalworking processes is examined in terms of material evidence, and other aspects relevant to the use and properties of the metals, with specific reference to the nature of the tools required.

1.2. Properties of metals: definition of the terms applied

> 'The ability of metals to deform plastically is ... the characteristic that makes it possible to change their shape relatively easily so as to form them into useful components.' (Samuels 1988, 286)

Unlike most other materials used in antiquity, metals are capable of being permanently deformed by mechanical working, enabling the creation of a desired shape by forging and other methods of working (Scott 1978). The three fundamental mechanical properties (Higgins 1973, 57-8) which govern the ease of working metals are:

a) Malleability - the ability to withstand deformation under compression without rupture
b) Toughness - the capacity to withstand stresses such as bending without fracture
c) Ductility - the ability to undergo permanent deformation under tension without rupture.

The mechanical properties of individual metals are not necessarily directly related to each other, nor to their physical properties (Higgins 1973; Samuels 1988). Moreover, they may be altered by alloying and by increases in temperatures. The mechanical properties, and the physical properties of hardness and strength, are characteristic of the elastic properties of the individual metal.

Permanent deformation, through techniques such as hammering, pressing, and swaging, occurs when the elastic limit is exceeded, and the metal is then said to be plastically deformed (Samuels 1988, 66-7, 287). Deformation is enabled by 'slip', that is, displacement of parts of the individual metal crystals with respect to one another. During cold-working, stresses are built up within the crystal structure and distorted regions (dislocations) impede further slip. Greater force is then required to effect further deformation, and the metal becomes work-hardened. Ultimately, no further work is possible and the metal is liable to fracture. However, the stresses may be relieved by annealing, namely by heating to a moderate temperature. Further cold-work is then possible, and in addition the strength and hardness are reduced, and the toughness is restored.

When metals are hot-worked, the internal stresses are mitigated by simultaneous 'recovery', and in addition, less force is required to deform the metal (Samuels 1988, 317-8).

The mechanical properties of metals are not readily expressed in simple numerical terms, but may be deduced from comparative mechanical testing methods (Higgins 1973, 58). Hardness and strength are more easily expressed numerically, and since these properties are a function of elastic characteristics, their measurement can also be correlated to the ease of working of metals with respect to the force necessary.

Hardness is determined by the amount of deformation (indentation) produced under a compressive force. In this study, the international standard Vickers pyramid hardness scale is used (expressed as HV or K/mm^2). For the metals under consideration, the range extends from a value of 4HV for lead to over 900HV for a severely quench-hardened steel.

Strength, the resistance to rupture or distortion, is normally measured in metals in terms of a tensile or stretching force, and provides a measure of the general strength of the metal, the ductility, and the ultimate tensile strength before failure (Smith 1933, 120; Higgins 1973, 58). For lead and steel, the range in ultimate tensile strength is $15N/mm^2$ for lead, to over $900N/mm^2$ for an annealed steel.

The properties of the individual metals are further compared in Section 1.6. Factors which may have been relevant in the selection of metals during the Iron Age are discussed in Section 1.7, and the basic qualities sought in metalworking tools are discussed in Section 1.8.

1.3. Ironworking

1.3.1. The introduction of iron, and its uses

Iron was worked by the third millennium BC in the Near East and eastern Mediterranean (Waldbaum 1980, 69-70), but it was not until the twelfth century BC that iron was worked in central Europe, attested by products of local type and the occurrence of ferrous slag (Champion 1980; Pleiner 1980). However, iron had no significant economic importance on the Continent until the eight century BC (Pleiner 1980; Wells 1984, 56, 90).

In Britain, iron artifacts have been found in association with metalwork and pottery of the Llyn Fawr phase of the Late Bronze Age, (seventh century BC, and equivalent to Hallstatt C in central Europe), with possible earlier occurrences of Ewart Park phase (Burgess 1979; Thomas 1989). The beginning of the use of iron in Britain may therefore date from around the eighth century BC, with iron 'replacing' bronze during the seventh century BC, the generally accepted transition period (Burgess 1979; O'Connor 1980; Thomas 1989). It is not until the sixth century BC (Ha D) in Britain that there is a more clearly distinguishable use of iron.

Hoards of Late Bronze Age metalwork occasionally contain iron artifacts, some of which are of undisputed British manufacture, such as the 'sickle' from Llyn Fawr, Glamorgan, whereas the sword and the spearhead from the same hoard (or series of deposits) are probable imports (Savory 1976a, 20, 53-5; Alexander 1981, 61). The ironwork in other Late Bronze Age hoards from England and Wales is often also uncertain in association (e.g. Gingell 1979), and sometimes of dubious identity (e.g. Curwen 1948, 162).

From earlier Iron Age settlements, stylistically early iron artifacts include Hallstatt-type iron pins, for example a swan's neck pin and a vase-headed pin from All Cannings Cross, Wiltshire (Cunnington 1923, pl. 21, 1 and 5), as well as a number of distinctly British ring-headed pins (O'Connor 1980, 257). Some early tools and implements seem to be copies in iron of Late Bronze Age types, for example a razor from Dinorben, Clwyd (Savory 1976a, 20, 74; and cf. O'Connor 1980, 265) and a socketed gouge with 'moulded' socket from All Cannings Cross (Cunnington 1923, 125, pl. 20, 2). There are also a number of looped socketed axeheads, though only two are from relatively secure contexts, and are assigned to the first centuries BC or AD (Manning and Saunders 1972; Scott 1974a).

Daggers or components of their iron sheaths which are of British origin are known from the sixth century BC (Jope 1961a; 1982), and some spearheads from the Thames may be early (Jope 1961a, 321; but cf. O'Connor 1980, 240). The earliest known native iron sword scabbard is from Orton Meadows, Cambridgeshire, which may date to the fourth century BC, and the sword may also be of British origin (Stead 1984a; 1985a).

Occasionally, ferrous slag has been found in earlier Iron Age contexts, for instance at All Cannings Cross (Cunnington 1923, 53-4), and Longbridge Deverill (Cow Down), Wiltshire (Tylecote 1983). These finds support the evidence for early local manufacture of ironwork

(Tylecote 1986) though there is as yet no certain evidence of large-scale production before the fifth century BC, for example at Castle Yard, Northamptonshire (Knight 1988).

Turnbull considers the paucity of evidence of ironworking from earlier Iron Age sites may be due to factors such as discard, failure to distinguish between ferrous and non-ferrous slags, or failure to recognise iron corrosion products on bronzework (e.g. from rivets) and to distinguish these from iron-pan (Turnbull 1984, 274-8).

The adoption of ironworking in the Near East and Mediterranean has been attributed to a break-down in supply of raw materials for bronze, in particular, tin (Maddin *et al.* 1977, 61; Waldbaum 1978, 73). More recently, it has been suggested that fuel shortage possibly due to deforestation, and because iron ores are more economic on fuel during smelting, may also have been a major factor (Waldbaum 1989). Ironworking was adopted in communities familiar and competent with non-ferrous metallurgy (Champion 1980), perhaps resulting from the use of iron oxide ores as fluxes during copper smelting (Charles 1980, 165-7). Analyses of artifacts (including jewellery) from the Mediterranean and Near East have lead some authors (e.g. Maddin *et al.* 1977; Waldbaum 1978) to conclude that one of the contributory factors for the adoption of iron in those regions was the technical superiority of steel over bronze.

It is now more generally agreed (e.g. Smith 1965; Champion 1980; Maddin 1984; Wells 1984; Barrett 1989) that iron was adopted primarily for social and economic reasons, in particular the more readily available iron sources. As Slater has pointed out, technological influences were not likely to have been motivating factors for the choice of specific metals if the products were non-utilitarian (Slater 1985, 48).

In Denmark, iron has been demonstrated to replace many types of tools made previously in stone, bone or antler, suggesting that the use of iron was not solely a replacement for bronze, nor necessarily related to technological benefits (Levinsen 1989).

Changes in political alliances and the disruption of trade relationships may have been dominant factors in the adoption of iron in some regions (Scott 1978; Rowlands 1980; Champion 1989). Social changes related to agricultural and political factors may have been the cause of hoarding of bronze during the Late Bronze Age in Britain, with the adoption of iron being an <u>effect</u> rather than the cause of the cessation of the large-scale use of bronze (Thomas 1989). The apparent decrease in bronze-working may also be due partly to changes in modes of deposition, which may contribute also to the apparent scarcity of iron during the earlier Iron Age and the later adoption of iron in western Europe (Bradley 1984; 1988).

Where analysis of large numbers of artifacts have been undertaken from geographically related assemblages in central Europe, ferrous technology has been shown to develop gradually throughout the first millennium BC. By the first century BC there is a noticeable increased incidence of the use of steel, of more complex forging techniques, and of the use of heat-treatments to improve properties (cf. Pleiner 1980, tables 11.1 and 11.3). The enhancements in technology, expressed typically in edge tools, agricultural implements, and weapons (Childe 1949; Pleiner 1980; Wells 1984), may therefore have been one of many influences for the continued and possibly enhanced use of iron during the later Iron Age.

In Britain, the use of iron seems to have increased dramatically during the latter part of the Iron Age, though this was also a period when deliberate depositions of metalwork (e.g. hoards, burials, ritual deposits) were more common (Bradley 1987), and thus the apparent increase may be exaggerated. At the systematically excavated site of Danebury, Hampshire, the loss and discard of iron has been demonstrated to increase during the latter period of intensive occupation (Cunliffe 1984b, 556, table 97; Ehrenreich 1985, figs 6.2 and 6.4). Alexander considers that the use of iron increased from the second or first centuries BC, with regional variations in adoption and scale of use related possibly to the availability of iron sources and population size or movement (Alexander 1981) .

<u>Uses of iron</u>

As indicated above, the earliest uses of iron in Britain include at least weapons, tools, agricultural implements, and personal items.

During the later Iron Age, iron continued to be used for these purposes and included also a broader range of products, presumably depending on social, military, and economic needs. The surviving artifacts range from fine mail (e.g. Foster 1986), to massive items such as hearth furniture and amphora stands (Piggott 1971), and cart tyres and chains (Fox 1946, 74, 84). Occasionally iron was used for items which seem to have been more frequently produced in non-ferrous metals, for example torcs (Clarke 1954, 51) and mirrors (Stead 1979, 81-2).

On composite metal items, iron was sometimes reserved for the undecorated (or 'functional') components, for example the shanks of linch-pins and terrets (e.g. Stead 1979, 45, 50-2), and sword scabbards and dagger sheaths - where iron was not infrequently employed for the back-plates and strap-loops (Piggott 1950; Jope 1961a). However, on the Continent, it seems that some types of products were more commonly made in iron than surviving examples suggest was the case in Britain, of which sword scabbards are a prime example (Piggott 1950; and cf. de Navarro 1972).

Iron is more susceptible to corrosion than non-ferrous metals, and thus decoration and identity may not always be recognised. Ironwork was not infrequently decorated, either during the forging stage, or subsequently by cold-worked surface techniques. For example, decorative elements and detail was added to items such as hearth furniture (Saunders 1977), including the twisting and counter-twisting of handles for symmetry of balance on cauldron hangers (e.g. Boyd Dawkins 1902) and implements such as pokers (Chapter 3.2).

Surface decorative techniques such as engraving and chasing have been recognised more recently on swords, scabbards, and spearheads (e.g. Stead 1979; 1984a; 1984b). Many iron fibulae, pins, and bracelets were presumably decorated by cold techniques since fine detail would be difficult to effect by hot-forging.

Tools were also occasionally decorated, for example a 'saw'-blade (Plate Ia) and a file from Fiskerton, Lincolnshire, both also fitted with decorated antler handles (Chapter 5.5.b). These, and many other examples, indicate that the ironworkers were not concerned solely with the production of utilitarian products.

'Currency bars'

The so-called iron 'currency bars' were very possibly part-smithed bars judging by the generally poor quality of iron and low degree of forging (e.g. Hedges 1979, 165; Ehrenreich 1985, 60). However, their function is uncertain.

Over 1,400 bars are known, from 47 or more sites in southern

Britain (Allen 1967; R. Hingley forthcoming). There are three major types: slightly tapered sword-shaped bars, narrow and pointed spit-shaped bars, and short plough-share bars - all of which have pinched sockets of various forms (Allen 1967). Many bars occur in hoards, some of which were bound or boxed together (Allen 1967; Sellwood 1984; Trow 1988).

A corrupt passage in Caesar's *de Bello Gallico* (V.12) has led to the long-held view that these bars were standardised in weight and were early forms of currency (e.g. Smith 1905a; Van Arsdell 1989). The generally accepted date for their manufacture is from the mid-Iron Age until the introduction of coinage (C. Haselgrove pers. comm.), though circulation may have continued until the mid-first century AD (Allen 1967, 322; Trow 1988, 37).

A number of the sword-shaped and spit-shaped bars have traces of wood in their sockets (Allen 1967, 331; Stead 1984c; Sellwood 1984, 359), interpreted by Allen (1967) as the remains of handles. From the position of the individual bars in a hoard found in a pit at Danebury it was concluded that the wood did not project beyond the sockets, and that in these bars the wood is the remains of formers rather than handles (Sellwood 1984, 359). It has been suggested that the sword-shaped bars may have been sword 'moods' (Tylecote 1962, 206-11), but it is difficult to reconcile the presence of sockets if these were intended principally as sword blanks. The weight of individual bars may reflect the standard (smithed) bloom (C. Salter pers. comm.).

Single finds or groups of bars have been found at seventeen or more sites where there is evidence of ironworking (Chapter 5). Fragments of bars, some possibly the remains of currency bars which have been cut up or broken, occur at a number of these sites: Danebury (Sellwood 1984, 357), Hod Hill, Dorset (Allen 1967, 324-6), Maiden Castle, Dorset (Wheeler 1943, 277), South Cadbury, Somerset (Alcock 1980, 697), Winklebury, Hampshire (Smith 1977, 106), and possibly at Gussage All Saints, Dorset (Wainwright 1979, 106), Meare Village West, Somerset (Gray 1953, 245), Midsummer Hill, Hereford and Worcs. (Stanford 1981, 126), and Worthy Down, Hampshire (Hooley 1931, 185). None of these fragments was associated with iron-smithing residues.

Fragments of currency bars, whether cut or broken, need not necessarily indicate industrial use (R. Hingley forthcoming, pers. comm.) since ritual bending or breaking of artifacts is not uncommon in certain types of contexts (Manning 1972; Bradley 1982; Fitzpatrick 1984) including deposits of ironwork comprising swords and metalworking tools (Manning 1980).

Currency bars have been found with ferrous metalworking tools in a 'hoard' of ironwork at Hod Hill (C. Saunders forthcoming) and at Madmarston, Oxfordshire (Fowler 1960), and in the probable multi-phase ritual deposits at Llyn Cerrig Bach, Gwynedd (Fox 1946), though they occur also in other ironwork hoards which do not include metalworking tools, for example at South Cadbury (Alcock 1969, 36).

Frequently, bars have been found in settlement boundary situations, most or all of which were probably ritual in deposition (R. Hingley forthcoming), and many of these are from sites where no certain iron-smithing activity has yet been recognised. Other bars occur in rivers and other types of contexts which also have ritual significance, and, in addition, these contexts often define boundaries (R. Hingley forthcoming).

Despite the paucity of evidence of ironworking associations, the simplest functional explanation is that they were part-smithed bars, primarily a means of transportation of raw iron, and shaped for easy conversion into blades, implements, or smaller items. Their common occurrence away from iron-smithing contexts favours ritual deposition, possibly symbolic of industrial and agricultural production and related to power control (R. Hingley forthcoming) rather than any direct connection with ironworking.

1.3.2. Iron sources and smelting

Iron ores are widespread in Britain (Tylecote 1962, 173, fig. 43, table 63), some of which are known to have been exploited in antiquity (Tylecote 1986, 124-7, tables 67-8). Strabo, writing in the late first century BC, records the export of iron from Britain (*Geography* IV, 5.2). However, the two continental-type bars (*spitzbarren*) from Portland Down in Dorset (Buckman 1868, 56-7) suggest that iron was not used from indigenous sources, though these bars were possibly from burials and may therefore have had other roles.

The main types of iron ores in Britain are limonite (found principally in the Forest of Dean and South Wales) and iron carbonates (occurring as sedimentary deposits in Northamptonshire, Lincolnshire, Oxfordshire, and the Cleveland Hills, and also as nodules or clay iron-stone e.g. in the Weald). Another source of iron is 'bog iron' ore, a deposit formed under wet conditions, and widespread in northern and western Britain (Tylecote 1986). Bog ore was smelted at the Iron Age sites of Bryn y Castell and Crawcwellt in Gywnedd (Crew 1987; 1989). Other sources which may have been exploited in the Iron Age include pyrites (occurring as nodules on chalkland), haematite (found mainly in Cumbria), and various iron deposits found in association with non-ferrous metal ores (Tylecote 1986, 125).

During the Iron Age, and until the medieval period, iron was smelted by the direct reduction of the ore (the bloomery process), in which the metal remained solid while the slag liquated away removing the unwanted waste (gangue) materials to the base of the furnace. The types and mechanisms of smelting furnaces are described by Tylecote (1986, 132-6), and further comments, on the formation of steel in particular, are given in Chapter 4.2.

The product of the smelt, the bloom, was porous and contained a high volume fraction of slag, often in the region of twenty per cent (Tylecote 1986). Loosely adhering slag, unspent fuel and other debris was probably removed by hammering (fettling), and the bloom then hammered hot (*c.* 1200°C) to expel the bulk of the slag and to consolidate the metal particles (cf. Crew and Salter 1989). During this process, the bloom would probably be reduced in thickness and repeatedly folded and hammered. When the slag was reduced to a minimum, *c.* five per cent by volume (Tylecote 1987, 316), the billet was then ready for forging.

Blooms

Only a few possible blooms or billets are known from the Iron Age - from Danebury (Sellwood 1984, 371, fig. 7.26), Dinorben, Clwyd (Davies in Gardiner and Savory 1964, 226-7), Little Waltham, Essex (Drury 1978, 32, 115), and of less certain date from Lesser Garth, Glamorgan (Savory 1966, 36, fig. 3, 4). Two cited by Tylecote (1986, 144) as possible Iron Age blooms seem to be of unlikely Iron Age date: the one from Wookey Hole in Somerset is from a context which yielded Roman pottery and other artifacts (Balch 1913, 577), the one from Crowhurst in Sussex has no associated finds (Smythe 1937) and is as likely to be from post-Iron Age activity.

Tools

Tools seem to have had no function in smelting except possibly to rake the bloom from a furnace. Anvils and hammers would have been used for the preliminary forging of the bloom. Stone anvils and hammers, which presumably served this purpose, have been found at Kestor (Fox 1954), Bryn y Castell (Crew 1987), and Crawcwellt (Crew 1989).

Potential waste materials (and other indicators of iron-smelting)

The identification of smelting sites relies principally on evidence of structural remains of furnaces, such as furnace bases or slag pits, heavily vitrified furnace linings sometimes with tuyère mouths, together with the presence of smelting slag (McDonnell 1983; 1988a). Sometimes slag survives as discrete furnace bottoms from 'bowl' furnaces, or as blocks from slag-pit furnaces. More frequently, smelting slag is found as fragmented pieces resulting from the breaking open of a furnace to extract the bloom, or from the raking or tapping of a furnace (McDonnell 1983). Occasionally, dumps of raw or roasted ore are found, as for example at Crawcwellt (Crew 1989), or hearths which may have been used for the preliminary smithing of the bloom, for example at Kestor, Devon (Fox 1954; Tylecote 1986, 140).

Fuel ash slag, formed by the vitrification of alkali from fuel, is also commonly found, though is non-diagnostic of the high temperature processes from which it was derived (Evans and Tylecote 1967).

1.3.3. Iron-smithing

Iron-smithing requires only a small open hearth, with enforced draught from bellows to increase the rate of combustion of the fuel sufficiently to raise the temperature of a part of the fire. Dry wood burns rather inefficiently for the high temperatures required. Thus, charcoal was probably the most commonly used fuel, though peat may have been employed in the highland zone (Tylecote 1986, 223-5). It has been estimated that a 30:1 weight ratio of charcoal to finished product would have been required for the smithing of the bloom - a third of the total amount of charcoal for the full production process from ore to product (Salter and Ehrenreich 1984, fig. 10.1).

The conditions within a charcoal-fuelled hearth may be oxidising, neutral, or reducing, depending on the air flow and the charcoal size, though oxidising conditions usually prevail (Tylecote 1986, 173, 318, fig. 115).

It is not known if hearths were at waist-height, as today, or if they were at ground level, but possibly both types were used, a raised hearth perhaps for a more permanent forge. However, raised structures seldom survive archaeologically, and only the foundations of hearths are likely to be found (McDonnell 1983).

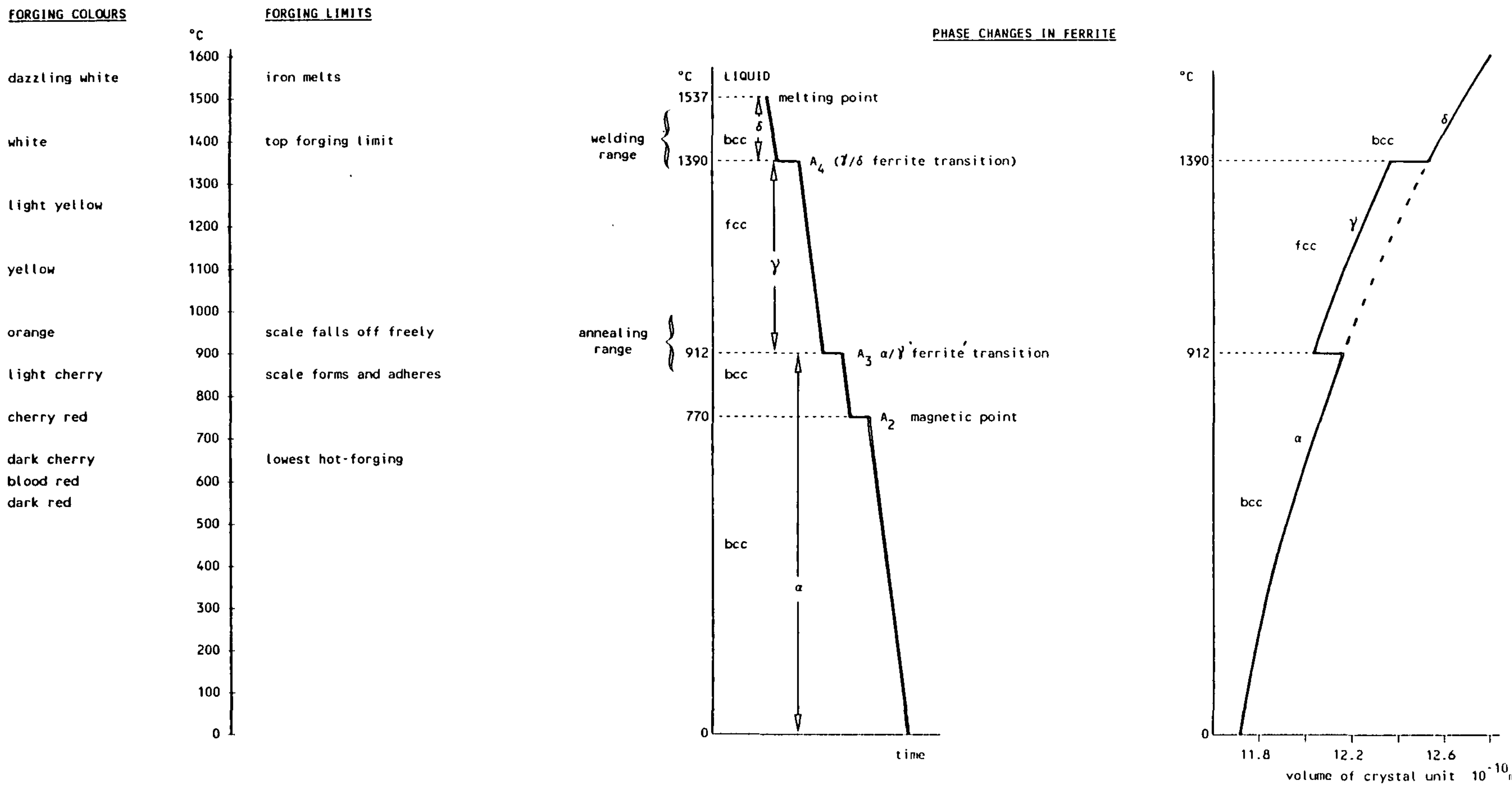
Iron is a relatively tough but soft metal which may be cold-worked, for example hammered into sheet or cut with a chisel or graver. Its usefulness results from its extreme malleability at high temperatures, and particularly its ability to be forge-welded, and to be strengthened and hardened to high levels. The most significant enhancements in properties are a result of carburization of iron to steel (an iron-carbon alloy), and of heat-treatments to alter the properties both of iron and of steel. These properties depend on solid state changes within the metal at various temperatures.

Since the forging conditions of irons and steels are particularly relevant to the manufacture and technology of the tools which are the subject of this study, the working conditions and the principal metallurgical effects are examined. It seems likely that the Iron Age metalworker judged the condition of the iron, and worked the iron, in a similar empirical manner as a modern blacksmith. Thus, on the basis of modern practice (e.g. CoSIRA 1955; Andrews 1977), the working conditions for forging plain (ferritic or phosphoric) iron are described first, followed by a discussion of the alterations in properties and the working conditions when iron is carburized to steel.

Iron (ferrite)

Plain iron is usually forged between 650°C and 1200°C and it becomes more malleable as the temperature is increased within this range (Andrews 1977, 118). During heating and subsequent forging, iron oxide scales rapidly develop and form brittle and adherent layers at low and intermediate temperatures (Samuels 1980, 477-83). However, above 850°C the scales are only loosely adherent due to air cavities within the layers, as well as volume changes in the crystal form, and these scales are readily removed by tapping the iron, and by contraction during cooling.

Today, a blacksmith judges the working condition of the iron by the nature of the oxide scale during heating in conjunction with incandescent colour changes of the iron. Figure 1:1 compares the



Based on Andrews 1977, 112, 118, with additions from Higgins 1973, fig. 4.6, and Samuels 1980, fig. C1, table C1,
fcc = face-centered cubic crystal
bcc = body-centered cubic crystal

Figure 1:1 Physical changes during the forging of plain iron structural (phase) changes of iron at different temperatures, and indicates the characteristics which are used today by blacksmiths to judge the condition of the metal.

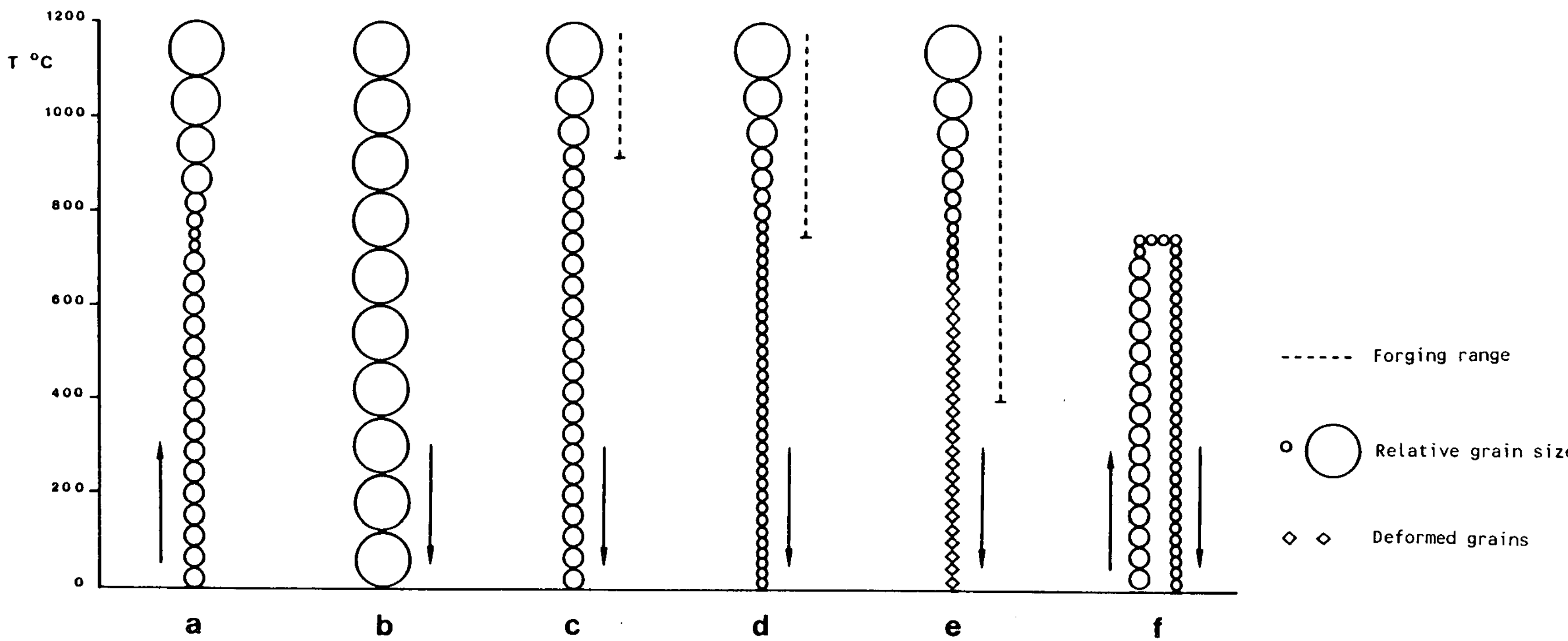
The principal forging conditions for plain iron are at yellow heat, around 1000-1200°C, when the metal is malleable and the scale falls away readily, but at these elevated temperatures the iron is subject to grain growth and thus a weaker structure (CoSIRA 1955, 19; Andrew 1977, 106). However, the grains may be refined to a smaller size, giving greater strength and toughness, by continuous hammering as the metal cools (Andrews 1977, 106-7).

Figure 1:2 shows the effect on grain size according to the temperature attained and the temperature range over which the iron is worked. The smaller the grain size achieved, the stronger and tougher is the iron (especially Fig. 1:2d). Annealing, to relieve stresses in the grains, may be achieved at a relatively low temperature, but if the iron is heated above the recrystallisation temperature of 650°C, grain refinement also occurs (Fig. 1:2f). However, this is a time dependent process according to prior cold work and other factors (Digges *et al.* 1966, 10; Samuels 1988, 308-11), and if a full 'anneal' is required to obliterate the effects of previous work, a temperature of around 900°C is required (but a lower temperature for steel).

Iron may be welded under pressure and heat; the surface grains are deformed and recrystallisation occurs at the interface (Samuels 1988). For plain iron this is normally performed above 1300°C (white heat), when the grains are most plastic and oxide scale is fluid (Andrews 1977). After the initial joining of the grains (on scale-free iron and usually in one massive stroke), the joint is then repeatedly hammered during cooling in order to consolidate the weld and to refine the grain size.

The malleability of iron enables easy reduction by hammering to draw down the cross-sectional area (Pleiner 1962, figs 40, and 44-46). Iron may be thickened by upsetting (Bealer 1969), or by folding and welding - termed 'pile-forging' or 'strip-welding' (Pleiner 1962; Scott 1974a), for which there is evidence of these techniques having been used in the Iron Age (e.g. Saunders 1977; Lang 1987). Figure 1:3 illustrates techniques of thickening iron and of welding by these methods. Pile-forging tends to create a lamellar structure which is visible microscopically (Chapter 4.3.1).

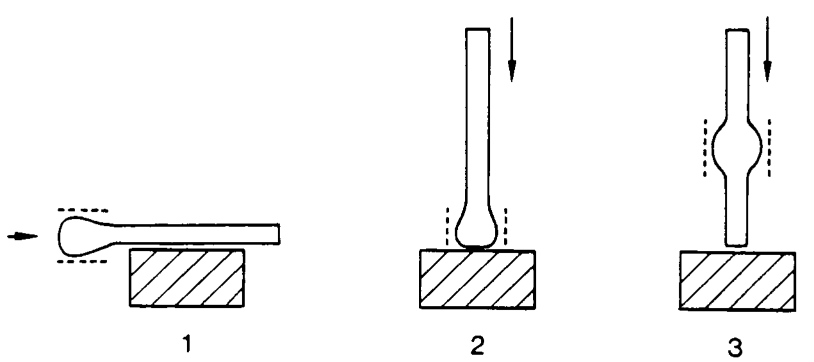
Figure 1:2 Diagrams showing the effects of heat and forging on the grain size of iron and steel



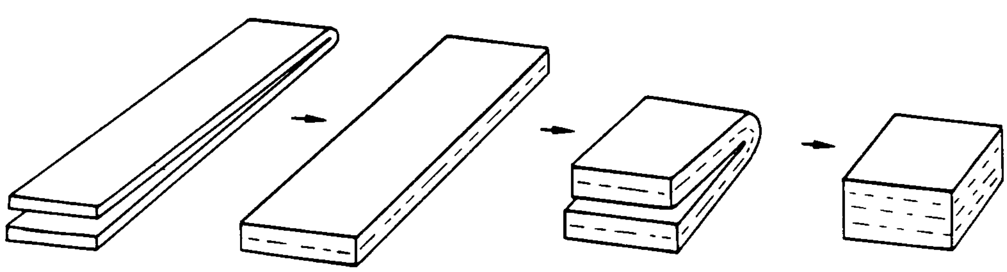
Iron requires a higher heating temperature than steel before grain refinement in a and f. The conditions relate to the normal forging cycle; factors such as prior cold work, and the presence of carbon and impurities in the iron, affect the temperatures at which recrystallisation occurs. After Higgins 1974, fig. 8.3.

a) HEAT (initial grain refinement, then grain growth as temperature increases)
b) COOLED FROM HIGH TEMPERATURE, NO FORGING (large grain structure)
c) FORGED AT HIGH TEMPERATURE (medium grain structure)
d) FORGED THROUGH TO INTERMEDIATE TEMPERATURE (very small grain structure)
e) FORGED DOWN TO LOW TEMPERATURE (very small grain structure but the grains are deformed due to working below the recrystallisation temperature)
f) ANNEALED (small grain size)

a) **Upsetting:** compressing by hammering (1), or by dropping onto a hard surface (2 and 3), the iron heated only at the region to be expanded



b) **Pile-forging:** to increase thickness, or to assist removal of slag inclusions to homogenise the structure



c) **Welding:** to thicken and form (left), to join two pieces of iron (right)

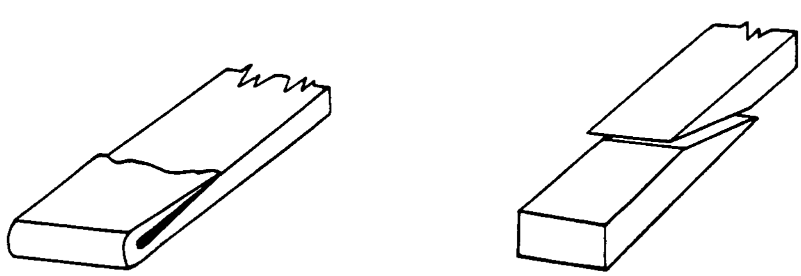


Figure 1:3 Iron forging: diagrams showing upsetting, pile-forging and welding

As the metal cools during forging, passing from red to black heat, the oxide scale becomes more adherent and the metal less malleable. At low temperatures, the metal is still workable but with less ease, and internal strains are created in the grain structure (Fig. 1:2e). These may be removed by annealing, or may be harnessed for their hardening effect on the metal, particularly if impurities such as phosphorus or arsenic are present. The hardness of annealed pure iron is *c.* 75-100 HV, whereas cold-worked iron containing 1% phosphorus reaches 340 HV (Tylecote and Gilmour 1986, tables 2 and 3, based on experimental work by J. G. McDonnell). However, phosphorus also makes the iron brittle at normal temperatures ('cold-short') and therefore unsuitable for many tools, blades, and other products.

The iron scales which exist on cooled iron are principally magnetite (Fe_3O_4) and haematite (Fe_2O_3), depending on the partial pressure of oxygen in which they are formed (Samuels 1980, 177-83, fig. 136.9). These oxides are appreciably hard: magnetite *c.* 450-550 HV, haematite *c.* 1000 HV (Samuels 1980, 477). Today, iron scales are often left *in situ*, or are removed by grinding (e.g. with abrasive stones). During the Iron Age, it seems likely that scales would have been removed at least from cutting edges and from surfaces which were to be decorated by cold techniques such as engraving.

<u>Carburized iron</u> (steel)

Bloomery iron invariably contains some carbon, and during the Iron Age, smelting conditions may have been controlled deliberately to enhance the carbon composition (Chapter 4.2). Nevertheless, any carbon was probably unevenly distributed throughout the bloom, ranging from carbon-free to carbon-rich zones (up to *c.* 1.2% carbon).

Carbon may also be introduced into the surface layers of a piece of iron by heating it above 900°C, either in the reducing part of a hearth (Tylecote 1986, 173), or with finely powdered charcoal or other carbonaceous material (Tylecote and Gilmour 1986, 15, fig. 5, tables 4-5). Strips of iron carburized in this manner may be piled, welded, and homogenised to enhance the carbon within the mass of iron.

From Britain there is some evidence that surface carburization was practised during the Iron Age (Chapter 4.4.2), but very limited evidence for the subsequent piling of the iron (e.g. Lang 1987, 62). A possible carburization hearth was found in an Iron Age hut at Catcote, Tyne and Wear (Long 1988, 20-1).

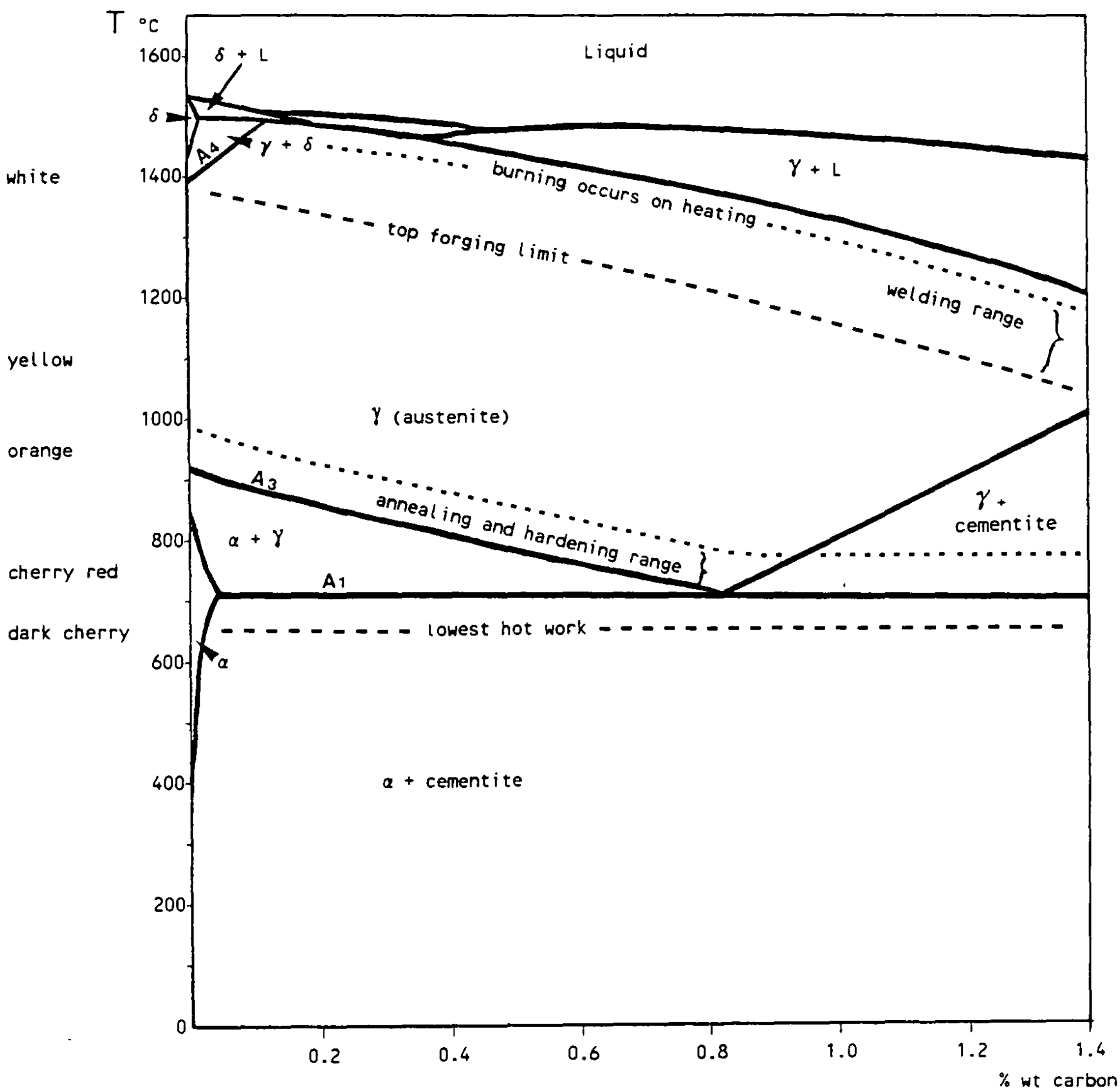
During heating, iron undergoes allotropic changes in crystal structure (Fig. 1:1) which alter the physical and chemical properties. The most important effect is the ability to absorb and retain carbon when it is in the face-centred cubic crystal structure (gamma-iron or austenite), whereas the body-centred crystal structure (α-ferrite) cannot retain any significant amount of carbon in the crystal lattice.

With reference to the iron-carbon phase diagram (Figure 1:4), it is seen that the vital phase changes for the hot-working of iron, A_3 (α-ferrite/austenite transition, or the Upper Critical Temperature) and A_4 (austenite/δ-ferrite transition), occur at lower temperatures as the carbon content increases and approaches eutectoid (0.83% carbon) composition. For example, on heating, iron becomes austenitic at 912°C (given time to equilibrate), whereas a 0.4% carbon steel becomes austenitic at *c*. 820°C, and a 0.8% carbon steel at 727°C (190°C lower than pure iron). Pure iron melts at around 1537°C, whereas 0.8% carbon steel starts to liquate 160°C lower.

These temperature differences in phase transitions affect forging operations, particularly when iron and steel co-exist in the bloom or when iron and steel are welded together. From Figure 1:4, it may be seen that the welding temperature of iron is close to the melting temperature of a eutectoid steel. Hence considerable care is required when welding iron and steel together in order not to overheat and 'burn' the steel component.

Steel has a narrower working range than iron (CoSIRA 1955; Andrews 1977). Iron is worked at 750°C (cherry red) for light forging operations such as bending and hot chiselling, *c*. 850-950°C (orange heat) for annealing, 1000-1300°C (yellow heat) for drawing-down, upsetting, and heavier forging, to 1300-1450°C (white heat) for welding (Fig. 1:4). For eutectoid steels, the range is 750°C (cherry red) for light forging, around 800°C (bright cherry red) for quenching and annealing, up to 1200°C for heavier forging, and 1200-1350°C (light yellow) for welding.

In addition to differences in forging temperatures, at the higher temperatures required for welding iron, the scale largely comprises wüstite (FeO), with a melting point of *c*. 1370°C (Weast 1977, B-121), and is therefore molten and readily squeezed out during welding. At the lower temperature required for welding steels, the



Redrawn from Andrews 1977, 113, with additions from Samuels 1980, fig. C1

A_1 = eutectoid temperature of steel
A_3 = austenite/γ- iron Upper transition temperature
A_4 = austenite/δ-ferrite transition temperature
L = liquid
cementite = Fe_3C
austenite = solid solution of carbon in γ- iron

Figure 1:4 Iron-carbon constitutional diagram (to 1.4%C) scale is barely molten, though addition of a flux such as sand to the surface reduces the flowing point of the scale to around 1200°C (Tylecote 1987, 248) by combining to form fayalite ($2FeO.SiO_2$), which also protects the metal from further oxidation (Andrews 1977, 64-5). It is generally thought that fluxes may have been employed during the Iron Age in order to compensate for these difficulties (e.g. McDonnell 1986a; Lang 1987).

The Iron Age metalworker, using heterogeneous irons, or steels of uncertain carbon composition, may have had considerable difficulty judging the forging condition of the metal. Welding and quenching, which require close control of the condition and hence temperature, would have been difficult operations to perform successfully.

The presence of carbon strengthens and hardens iron (Figure 1:5a) due to the formation of cementite (Fe_3C) or pearlite (ferrite/cementite eutectoid). A steel may be hardened appreciably more by quenching from the austenitized condition by rapid cooling, such as plunging it into a bath of water. A hard and brittle constituent is formed which is known as martensite. In a severely quenched steel, if the microstructure formed is wholly martensitic, a hardness of over 900 HV may be achieved (Figure 1:5b). However, if the carbon is non-uniformly distributed, quenching will produce localised areas of martensite together with soft ferritic regions, producing a steel of low overall hardness.

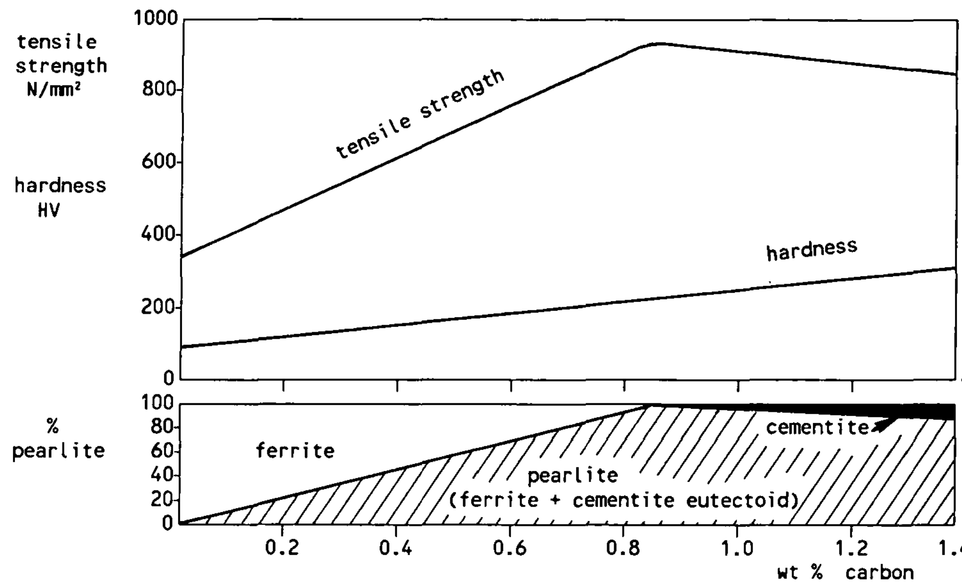
Martensite is very brittle, but this may be reduced at the expense of hardness by reheating the steel to low temperatures (200-350°C), in order to modify ('temper') the properties appropriately for the function of the artifact. There are also less severe methods of quenching which produce a variety of intermediate constituents, which are discussed in Chapter 4.4.4.

To summarise, iron may be hardened in the following ways:

a. Refining the grain size during hot work
b. Cold-working, particularly if high in phosphorus
c. Increasing the carbon content
d. Quenching (if carburized)

Numbers 1 to 3 above strengthen iron, whereas number 1 also increases toughness (as does annealing), but 2, 3, and 4 embrittle the

a) Annealed (air-cooled) condition. (After Higgins 1973, fig. 7.3)



b) Severely quenched from the fully austenitized condition, forming martensite.
(After Samuels 1980, fig. 90.12)

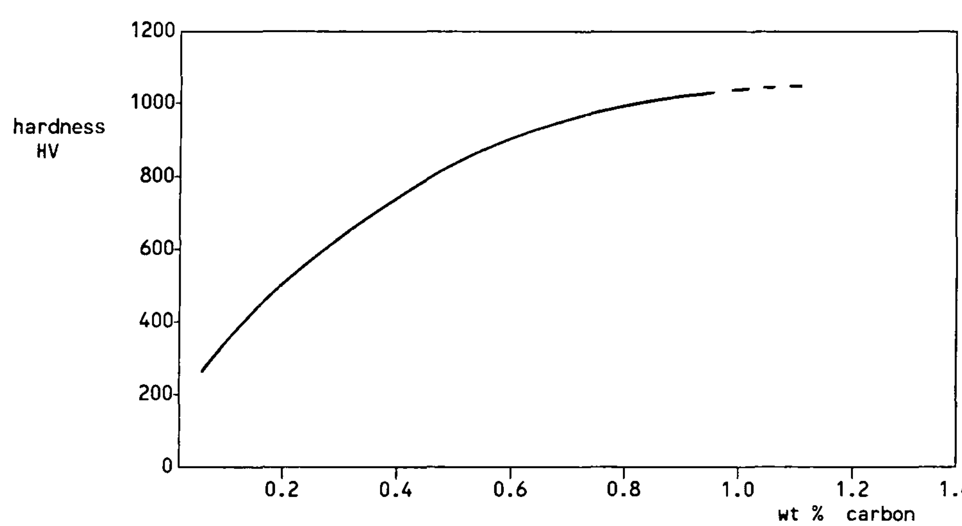


Figure 1:5 Relationship between carbon content, microstructure, hardness and tensile strength in steels

metal (though the toughness of quenched steel may then be restored or enhanced by tempering). The most resilient hardened irons are therefore those which have been carburized, grain-refined, quenched and tempered. To achieve all these features, considerable time and skill is necessary.

<u>Tools for iron-smithing</u>

The relationship of the individual ironworking processes, the residues produced, and the tools are shown in Figure 1:6.

The basic tools necessary are compared with those for other metalworking processes in Table 1:1, together with an indication of the tools which have not yet been recognised from the Iron Age in Britain. The known tools are discussed in Chapter 3.

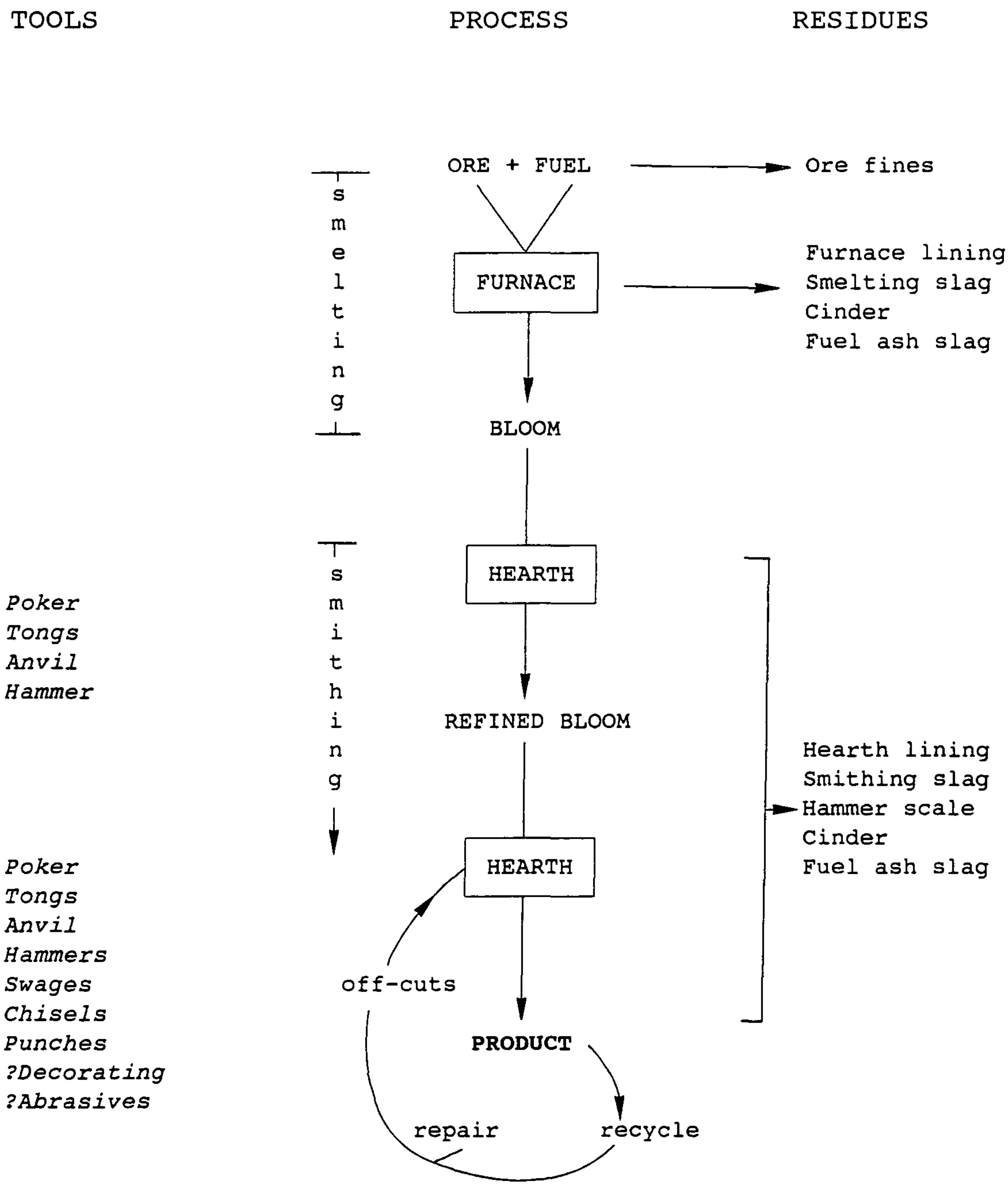
<u>Potential waste materials</u> (and other indicators of iron-smithing)

1. Hearth, hearth lining, tuyère etc: diagnostic of iron-smithing only if in association with ferrous <u>smithing</u> slag.
2. Smithing slag: comprising slag, hammerscale, unspent fuel and other debris, and possibly welding flux (e.g. sand) and iron silicate, and sometimes compounded as 'hearth bottoms' (McDonnell 1987, 48)
3. Plate (or flake) hammerscale: the iron oxide scale which forms during heating and hot-working, and is removed during forging (McDonnell 1987, but cf. Crew 1988b)
4. Spherical hammerscale: the 'sparks' thrown off during welding (McDonnell 1987, 48)

Other indicators of smithing may include tools, blanks, off-cuts, and associated archaeological features suggesting wind-breaks or bellows supports (e.g. Thompson 1983, 251; Crew 1987, 98). The non-diagnostic nature of fuel ash slag is mentioned earlier.

<u>Intermediate products</u>

Seldom have ferrous artifacts which can be described with any certainty as intermediate or part-worked products been recognised, though the so-called iron 'currency bars' discussed earlier may fall into this category. Occasionally structural forms of artifacts in conjunction with tool marks (such as chisel cuts) suggest that items may be off-cuts or artifacts during manufacture or alteration.



(After McDonnell 1988, fig. 2, with additions)

Figure 1:6 The iron-working sequence

Table 1:1 The basic tools and implements required for the various metalworking processes (excluding smelting and refining)

Process	Iron-smithing	Wrought non-ferrous	Casting	Composite technology	Coin making
Cutting	hot sets#, hot chisels#, cold sets, cold chisels	cold chisels			
Forming	set hammers#, hammers#, fullers#*, anvils#, swages#, mandrels#, punches#, drifts#	hammers, mallets, raising & sinking hammers, mandrels anvils, punches, swages, (draw-plates*)		hammers, punches	anvils/stocks•* hammers
Mechanical joins	hammers#	hammers, punches		hammers, punches	
Finishing	flatters#* files?	planishing hammers, files, scrapers, burnishers	files, scrapers, burnishers	files, scrapers,	
Decorating	punches•, hammers•, scribers, gravers, chasing tools	punches, hammers, scribers, gravers, chasing tools	(chasing tools, gravers)	punches, hammers, scribers, gravers, chasing tools	
<u>Accessories</u>					
Heating	hearth implements, tongs#	hearth implements, tongs#, ?blowpipes#*	hearth implements, crucible tongs(#)	hearth implements, tongs#, ?blowpipes#*	hearth implements, tongs(#)
Grinding	abrasives	abrasives	abrasives	abrasives	
Polishing	haematite?	haematite?	haematite?	haematite?	
Other	clamps*	clamps*, supports*	wax-modelling tools	clamps*, supports*	

used on hot metal • used on hot or cold metal * no known examples of the tool type from the British Iron Age

1.4. <u>Non-ferrous metal working</u>

1.4.1. The non-ferrous metals used, and their properties

The non-ferrous metals which were employed during the Iron Age were copper, tin, lead, silver and gold, though only occasionally do these metals seem to have been used in their relatively pure state. Apart from minor or trace amounts of impurities, the metals were normally mixed with other metals to produce alloys (Tylecote 1986; Bayley 1988; Northover 1988). In the pure condition these metals are very soft and malleable at ambient temperatures. Hardness and strength may be increased by alloying, and in copper, silver, and gold also by cold-working. Other effects of alloying include changes in colour and lustre, and reduction of the melting points.

<u>Copper alloys</u>

From surviving finds, the evidence suggests that the most commonly used non-ferrous metal species in the Iron Age, both for wrought products and for casting, was copper alloyed with tin (bronze), comprising upwards of a few per cent tin, but typically in the range 10 - 14% tin. Cast bronze usually had a few per cent lead added. Analyses of artifacts from sites including Danebury (Northover 1984a), Gussage All Saints (Spratling *et al.* 1980, 280-2), Glastonbury (Bulleid and Gray, 1911, 178, 245), Hengistbury Head (Northover 1987), as well as many individual finds (Tylecote 1986, table 20; Lowery *et al.* 1983, table 1) indicate that these were the normal range of bronze compositions, though occasionally considerably higher tin or lead contents are recorded.

High-tin bronzes ('speculum') have a white reflective appearance, and are known in first century BC cast coinage (Tylecote 1986, 114, table 61) and first century AD cast mirrors (Craddock *et al.* in Stead and Rigby 1989, 2).

Small amounts of zinc have sometimes been found in Iron Age bronzes, and in copper slag and dross, probably arising from the smelting of zinc-rich copper ores (Northover 1988; Musson and Northover 1989; Bayley 1990). Evidence of the deliberate alloying of copper and zinc (i.e. brass) occurs during the last decade or so of the Iron Age in Britain (Bayley 1984a; 1988; 1989), presumably due to Roman influence. The use of brass in the first century AD was mainly restricted to brooches, coins, non-functional ritual articles, and military items (Bayley 1990). Some brass artifacts may have been made from imported metal stock or blanks (Bayley 1985b) though others were probably imported in the finished condition (Bayley 1990). The earliest evidence so far of brass production in Britain comes from Claudian contexts (Bayley 1984a; 1990).

Bronzes with up to about 14% tin may be cold forged providing that the metal is first very thoroughly annealed to homogenise the as-cast structure, and subsequent annealing is necessary as the metal hardens through cold-working (Higgins 1973, 324). High-tin compositions are too hard and brittle to be cold-worked (Hansen and Pell-Walpole 1951). However, they may be hot-forged, and, if subsequently quenched under the right conditions they are appreciably softer and are then more easily cold-worked (Goodway and Conklin 1989).

The addition of lead up to 2% has been found to greatly enhance the flowing properties of bronze and to reduce porosity from shrinkage, enabling the production of more complex and intricate castings (Staniaszek and Northover 1982). Greater than a 2% lead content lowers the liquidus temperature of the bronze but produces little enhancement in other thermal properties (Craddock 1988). However, leaded alloys are brittle owing to the immiscibility of the lead in copper, and with high concentrations of lead, these alloys are not easily cold-worked (Hansen and Pell-Walpole 1951, 247-9).

Brasses with up to 30% zinc are relatively soft and malleable and are readily cold-worked. In zinc-tin bronzes ('gunmetal'), the mechanical properties tend to be governed by the tin content (Hanson and Pell-Walpole 1951, 247).

Tin and lead

Tin and lead were used as constituents of copper alloys, and individually for an apparently limited range of products such as weights, 'net-sinkers', spindlewhorls, and rings (e.g. Bulleid and Gray 1911, 241-53; Orme *et al*. 1981, 60). Tin was used for soldering (Lang and Hughes 1984), and for coating both iron and non-ferrous metals (Corfield 1985; Oddy and Bimson 1985; Meeks 1986).

Both tin and lead have low melting points and are very soft and malleable, and therefore are readily cast or wrought. Their low strengths and inability to be work-hardened (a consequence of their low recrystallisation temperatures) make them unsuitable for all but a few purposes. A small number of tin-lead artifacts are known from the Late Bronze Age (e.g. Needham and Hook 1988) and Iron Age (P. Northover pers. comm.), but these may have been from the accidental mixing of the metals rather than deliberate alloying.

Gold and silver

Gold and silver, and their alloys with copper, seem to have been used principally for coinage during the first centuries BC and AD, though gold staters were imported from the later second century BC (Haselgrove 1987). Torcs, bracelets and other items dating to first half of the first century BC are known in gold alloy (Clarke 1954; Owles 1969; 1971; Burns 1971; Brailsford and Stapley 1972; Tylecote 1986, table 3; Eluère 1987b), though some of these may be imports (Northover 1988, 230). The major influx of gold for coinage and other types of artifacts, notably during the second quarter of the first century BC, is attributed to cross-channel contacts as a result of the Gallic wars (Haselgrove 1987). The majority of the silver brooches and vessels known from the Iron Age in Britain are also probably imports (Stead 1984a, 60).

Both gold and silver, and their alloys, are very soft and easily worked; the addition of other metals, in particular copper, enhances their strength without undue reduction in malleability.

1.4.2. Ores, smelting, and refining

Copper deposits occur in the west of England, Wales, Ireland and Scotland (Tylecote 1986, fig. 7, table 6); tin ores occur in Devon and Cornwall (Tylecote 1986, 43; 1987, fig. 1.4); and deposits of lead and argentiferous lead ores are rather more abundant (Tylecote 1986, 54, fig. 22). Silver may have been extracted from the copper ores in Devon and Cornwall during the Iron Age (Tylecote 1986, 58). Gold occurs as a native metal in Cornwall, and at several localities in Wales, Ireland, and Scotland (Tylecote 1986, 1).

Trace element distribution patterns in Iron Age bronzes have been found to be different from those used in the Late Bronze Age, suggesting that new copper sources were located during the Iron Age, possibly in Dartmoor and Wales (Northover 1984b; 1987; 1988). Some metals may have been imported (Northover 1988; Bayley 1990).

The export of ores of tin, gold, and silver from Britain is recorded by Strabo (*Geography* III, 2.9; IV, 5.2).

There is little direct evidence for the smelting of non-ferrous ores during the Iron Age in Britain. The paucity of evidence for copper smelting during the prehistoric period may be due to a primitive non-slagging process having been used (Craddock and Meeks 1987).

The presence of tin ore and a possible furnace at Chun Castle in Cornwall (Leeds 1927, 216-8, 238-9) suggest that tin may have been smelted there (but cf. Tylecote 1986, 43). At Hengistbury Head there is evidence of smelting or refining of copper, the refining of silver, and possibly for alloying of copper with tin ore (cassiterite) to make bronze (Northover 1987; Salter 1987a, Northover 1988, 229). It is likely that metals were commonly recycled, and probably with some degree of selectively regarding composition and usage (Bayley 1990).

Copper was presumably refined and alloyed in crucibles, probably with the addition of a flux during refining to encourage the removal of oxidised copper and impurities, or with a charcoal blanket to reduce oxidation during alloying, and then skimmed of dross (oxidised metal and flux) before pouring (Smith 1933; Bayley 1988).

Silver was probably normally extracted from argentiferous lead by cupellation in an open hearth and then refined in a shallow crucible (Bayley 1988, 194).

Brass was relatively difficult to make since zinc vaporises at a temperature below that at which it is reduced from its ores. An intimate mixture of metallic copper, zinc ore, and charcoal as the reducing agent, was heated in a closed crucible and as the metallic zinc vapour was reduced it diffused into the copper (Craddock 1978; 1990).

The crucibles known from the Iron Age are predominantly triangular types with lipped corners for pouring (Bayley 1988, 194). These were heated from the top, and possibly manipulated with withies or tongs (Tylecote 1986, 99, fig. 52, lower). Other types of crucibles are known, including globular, dish, rounded, and handled forms, and these presumably had special functions (Northover 1988). Metals with high melting points require crucibles made of refractory materials (Howard 1983).

<u>Tools for smelting and refining non-ferrous metals</u>

The processes just described were principally crucible methods. Tongs may have been employed to manipulate the crucibles, and implements such as iron pokers to control the hearth and fire.

1.4.3. Moulds

The metals and alloys were cast to final shape, or to rough shape and then worked, or were wrought from cast ingots. The principal non-ferrous metalworking processes used in the Iron Age for which we have evidence are wrought-working and *cire perdue* (lost-wax) casting, which are considered separately below. The production of coins probably involved special techniques to cast the coins or blanks (Section 1.4.6). Other casting techniques were likely to have been used, particularly during the earlier Iron Age, but at present there is little evidence for the methods employed.

The sequence of the main non-ferrous manufacturing processes are shown in Figure 1:7, together with the residues produced, and basic tools which may have been used.

It is often difficult to tell from finished products if open moulds, clay piece moulds, or investment casting was used. Some artifacts may have been cast to final shape in open or two-piece stone moulds, although there is limited evidence for this - namely a two-piece sandstone mould from Worm's Head, Glamorgan (Savory 1974). Lead patterns for two-piece clay moulds or for investment ('lost lead') moulds are known from the Late Bronze Age (Needham and Hook 1988, but cf. Tylecote 1987, 211) and it is possible that similar master moulds, perhaps made of wood, were used during the Iron Age (Fox 1958, 75; Maryon 1944; Foster 1980, 22).

A chape from a fourth century BC dagger sheath has mis-aligned compass marks from the inscribing of the studs on the model for making the mould, suggesting therefore that a two-part clay mould was luted together to form a single mould (Jope 1961a, no. 19, and p. 328).

From Baldock, Hertfordshire there are three part-manufactured Colchester brooches which are roughly formed to shape (Bayley 1985b; Stead and Rigby 1986, 122-3), although it is not known whether these had been cast or wrought to the present form.

Ingots intended for later forging seem to have been cast in stone or clay moulds. Moulds have been found on a number of sites, and often these have hollows cut on more than one surface, and some are blackened (e.g. Gray 1966, 371-2), probably through heating the mould to drive off absorbed moisture prior to casting and to prevent breakage due to thermal shock when the metal was poured in. Stone

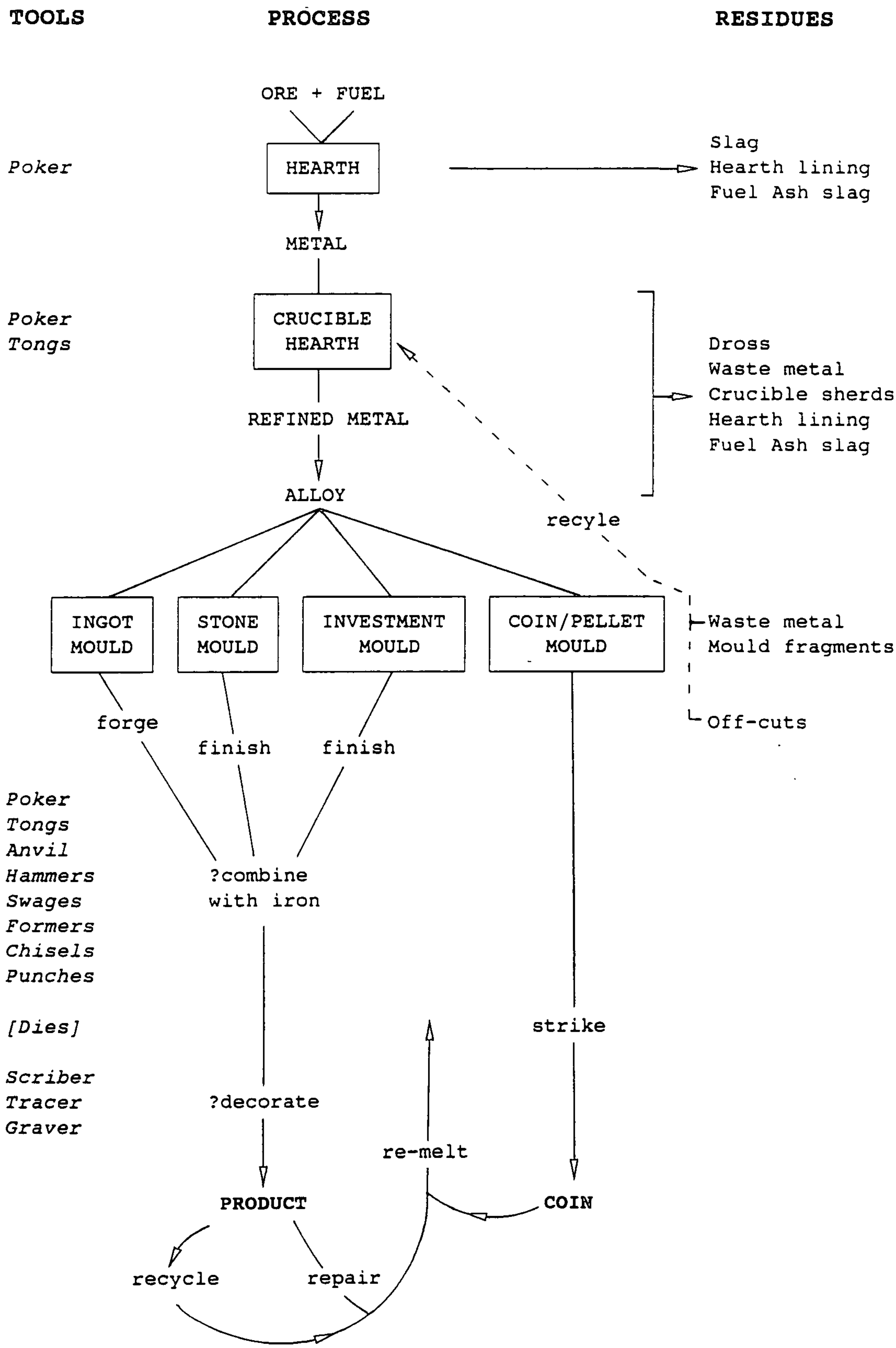


Figure 1:7 Non-ferrous metal processes

moulds seem to have a technological advantage over clay moulds in that the metal cools more rapidly and thus reduces segregation effects (Staniaszek and Northover 1982).

Presumably molten metal was normally poured from a crucible into the mould, but there is evidence for the direct melting of (scrap) metal in a clay mould at Mucking, Essex (J. Bayley pers. comm.). Clay moulds are less easily recognised, though there is another possible clay ingot-mould from Weelsby Avenue (J. Sills pers. comm.).

A few part-worked copper alloy billets bearing tool marks from hammering have been found; a narrow rectangular billet from Croft Ambrey (Stanford 1974, 162, fig. 74, 17) and two from Gussage All Saints (Spratling 1979, 130, fig. 98, 1; Wainwright 1979, 109, no. 3074), a disc from Ringstead, Norfolk (Clarke 1951, 223, pl. XIXb), and several ingots and billets from a hoard at Seven Sisters, Glamorgan (Davies and Spratling 1976, 133-5, fig. 10, nos 26, 27, 31 and 32). The Croft Ambrey billet and one from Gussage All Saints have been determined as bronzes containing *c.* 10-12% tin (Spratling *et al.* 1980, 282). Ingots and ingot-bracelets in gold alloy, silver alloy (see Northover 1988, 229-31), and bronze, were found in hoards B and C at Snettisham (Clarke 1954).

Clay moulds were also used for casting components together, for example copper alloy terminals on to iron shanks of linch-pins (e.g. Foster 1980, 18-19), or to assist the welding together of non-ferrous metals (Maryon 1949), for example handles on to bronze mirrors (e.g. Lowery *et al.* 1983, 286), and sword chapes on to scabbard frames (Spratling 1972, 257).

1.4.4. Wrought non-ferrous metalworking

Although metals tend to be more malleable at high temperatures (Samuels 1988, 317-8), non-ferrous metals are normally worked cold, partly because many of the techniques require close-handling of the metal (e.g. raising), but also because some alloys are 'hot-short' and therefore difficult or impossible to hot-forge. Leaded copper alloys are extremely 'hot-short' (Smithells 1967, 970), as are also unleaded bronzes with above 8% tin (P. Northover pers. comm.) unless specially heat-treated (Goodway and Conklin 1989). Moreover, during the heating of copper, silver, gold, and alloys from these metals, oxidation of the base metals (e.g. copper, from the constituent metals and impurities) form surface scales and sub-scale oxides, and these are likely to become incorporated into the metal and are detrimental to further working. However, there is some limited evidence of hot-working of bronze during the Bronze Age (Allen *et al.* 1970, 24).

The severe work-hardening effects which occur during cold-working, in alloys in particular, can be mitigated by annealing. Typically a temperature in the region of 600-700°C for a few minutes is required to anneal sheet bronze (Hansen and Pell-Walpole 1951, 296-302, 314), and silver alloys and gold alloys (Smith 1933, table III).

Today, the oxide scales which form during annealing are removed prior to further working by 'quenching' (plunging into a cold liquid) and pickling in a bath of acid (Smith 1933). Unlike steels, the quenching of non-ferrous metals does not harden the metal and may even result in a metal which is softer than if air-cooled, owing to the prevention of segregation effects which occur during the slow cooling of some alloys (notably silver-copper alloys).

Unlike iron, non-ferrous metals are not readily welded under pressure and/or heat (Tylecote 1978). Gold and silver in their relatively pure condition may be pressure-welded owing to their extreme ductility and freedom from oxidation (Tylecote 1978). The only cold pressure-welded artifacts known from prehistory come exclusively from Ireland; four sheet gold boxes date to *c.* 800 BC, and silver sheet artifacts to *c.* 400 BC (Maryon 1944; Wolters 1975; Tylecote 1978).

Range of wrought products

Iron Age artifacts which were manufactured by wrought techniques include rod and wire products such as rivets, torcs, bracelets, pins and brooches. Sheet-metal products include bucket mounts, vessels, shields and shield mounts, scabbard sheaths and plates, helmets, fittings, bindings and claddings.

Tools for wrought working

The basic tools which were presumably employed for the various wrought techniques of working are shown in Table 1:1. The known ferrous tools are discussed in Chapter 3, where comments on some of the individual techniques are also given.

Potential waste materials

The debris which may arise through the wrought working of non-ferrous metals includes hearth linings and fuel ash slag, off-cuts of metal and scrapings and filings, as well as vitrified crucibles, broken ingot moulds, and solidified metal or dross from metal preparation and ingot casting (Figure 1:7). Other indicators are ingots, billets, blanks, and part-manufactured items such as bar, strip, rod and wire which bear tool marks (particularly hammer facets and chisel cuts), as well as tools. Waste metal was probably recycled (Bayley 1990).

1.4.5. Investment casting

Cire perdue or lost-wax casting involves the investment of a wax model with a clay-sand mixture to form a one-piece mould (Coghlan 1975, 61-4; Howard 1980, 7; Hunt 1980; Tylecote 1987, 227-8). The probable sequence employed is as follows. The mould was dried and heated to a low temperature and the wax poured out through a 'gate'. The mould was then fired, and molten metal was added whilst the mould was hot in order to prevent freezing of the metal and damage to the mould through thermal shock. To extract the casting it was necessary to break open the mould, and thus each mould was used once only.

Occasionally castings involved the use of clay cores, sometimes because the construction required their use, and possibly also for economy of metal or to lessen the weight (Spratling 1972, 257). A hollow 'cheekpiece' from Bowerchalke in Wiltshire still retains the clay core (Spratling 1972, no. 232).

The use of beeswax or a wax-sand mixture for the making of models for investment casting is assumed since this is the only material known from the prehistoric period which has suitable properties and may have been available (P. Northover pers. comm.). A lump of yellow 'wax' (conceivably beeswax or rosin) was found with metalworking tools and scrap metal in a mid-first century AD hoard at Santon, Norfolk (Smith 1909, 158). Beeswax was also found inside a first century BC gold torc from Snettisham, Norfolk (Clark 1954, 37). Northover has noted that the earliest evidence for the honey-bee in Britain dates from the third century BC (Robinson 1984, 119), and he suggests that their introduction may have been linked with the need for wax for founding (Northover 1984b, 136).

In Britain, there is as yet no evidence for *cire perdue* casting before the mid-Iron Age (Northover 1984b, 136). The majority of the clay investment moulds which have been recognised come from first centuries BC/AD contexts, for example at Gussage All Saints, Dorset (Spratling 1979), Weelsby Avenue, North Humberside (J. Sills pers. comm.), and Fison Way, Norfolk (A. Gregory forthcoming), but some have been found in third or second centuries BC contexts at Beckford (Britnell 1974; Hurst and Wills 1987; Northover 1988). At present there are no certain castings made by this technique known before the third century BC (I. Stead pers. comm.). In central Europe, *cire perdue* casting may date from the early second millennium BC (Hunt 1980).

Range of products

From surviving mould fragments we know that chariot and harness fittings were commonly made by *cire perdue* casting during the later Iron Age. Occasionally moulds for other categories of artifact are recognised, for example a 'horn-cap' (Hurst and Wills 1987).

Tools required for *cire perdue* casting

Founding is a complex process in terms of the range of raw materials, but requires less working of metals and thus fewer tools compared with wrought working methods.

Implements would have been used to form the wax-models, and these could have been devised from any suitable material such as bone, wood, or metal. Four spatulate-ended bone implements were found at Gussage All Saints associated with debris from *cire perdue* casting (Spratling 1979, 141, fig. 98, 2-5). Other bone implements which may have been used for modelling wax are known from Weelsby Avenue, Glastonbury, Meare Village East, Meare Village West and Wetwang Slack (Chapter 5).

The castings may have required the removal of excess metal such as the sprues and gates, and the erasure of any casting blemishes. Some may have been worked with tools to complete the decoration (Howard 1980), though others required a considerably greater amount of work (Owles 1969; Brailsford 1971, 19, pls VIII and IX).

Potential waste materials

The likely debris from *cire perdue* casting includes mould fragments, crucibles and solidified waste metal from the pouring of the castings, metal-filled sprues and gates, mis-castings, and hearth debris from the melting of the metal (Figure 1:7). Waste metal was probably recycled (Bayley 1990), the wax was reusable (Tylecote 1987, 228), and crucibles would no doubt have been reused unless damaged or heavily vitrified. Since the moulds were broken open to release the castings and could not be re-used, their fragments may be expected, but these pieces are not necessarily of sufficient size to indicate the form of the product. In addition, since they were often only fired to low temperatures they are susceptible to weathering, making the type of product more difficult or even impossible to identify from mould residues if severely decayed.

1.4.6. Coin making

The earliest indigenous coins in Britain were cast high-tin bronze potins, possibly dating from the late second century BC, giving way to struck bronze during the later first century BC (Haselgrove 1987). The earliest gold coins of British origin, imitations of struck Gallo-Belgic staters, were produced from the earlier part of the first century BC. Struck silver units and fractions date from the mid-first century BC (Haselgrove 1987, fig. 5:6).

Cast coins were produced from inscribed two-piece clay moulds (Van Arsdell 1986), or by lost-wax processes (Dolley 1954; Collis 1984, 102), usually in multiples to give strips of coins in a single casting. After casting, the coins were separated from each other and the sprues by simply fracturing the metal, possibly along parting lines which had been marked in the mould (Van Arsdell 1986, 218). Moulds for casting potins are known from France (Haselgrove 1987, 29) but as yet none has been found in Britain.

Blanks may have been cast in open moulds or by allowing molten metal to solidify on a flat surface (Sellwood 1980; Collis 1984, 102). In addition, blanks may have been produced in the so-called 'coin pellet moulds'. These baked clay slab moulds have been found at thirteen or more sites in Britain. Their identification as moulds for the production of coin blanks is not universally accepted (Sellwood 1976; 1980, vii; Casey 1983) primarily because of edge irregularities in experimentally produced coins.

It has been suggested that these moulds may have had a pre-weighed quantity of metal heated *in situ* or molten metal may have been poured from a crucible, and the pellets so formed then struck hot, either to produce the coins, or to make flans which were neatened by hammering before striking (Tylecote 1986, 114-5; Van Arsdell 1989, 48). A number of these moulds from Britain and the Continent have been found with traces of metals in the clay matrix (Tournaire *et al.* 1982); those from Britain are summarised in Table 1:2. In addition, a silver-copper pellet was found in a mould at Old Sleaford (Jones *et al.* 1976, 140-1) and a bronze pellet was found in a mould at St. Albans (Frere 1958, 13). On the basis of the associated metals it has often been argued that the moulds were involved with the making of coins (e.g. Clifford 1961; Jones *et al.* 1976; Collis 1985; Van Arsdell 1989), though at present the evidence is inconclusive.

Tools for coin making

Cast coinage and the making of flans may have involved the use of tongs for manipulating crucibles, and hearth implements for the fire. Struck coinage may have required hearth implements, tongs, hammers, and dies (the lower die or 'anvil', and the upper die or 'stock'). From experimental work, Sellwood considers that bronze dies would have been suitable for the striking of coins providing that the blanks were well annealed and struck hot (Sellwood 1976; 1981).

Potential waste materials

The waste materials from coin production may include hearth debris, crucibles, waste metal, and moulds or their fragments. As already indicated, no definite coin making debris has been found in Britain, nor ferrous tools with certain associations with coin production. The preparation of blanks and the striking of the coins need not necessarily have occurred at the same location (Haselgrove 1987).

Table 1:2 Summary of metals detected in Iron Age 'coin pellet moulds'

Site	Principal metals	Reference
Bagendon, Glos	Silver/copper; brass	Richards and Aitken 1959; (Richards in Clifford 1961, 147-9)
Braughing, Herts	Silver alloys; Gold alloys	Craddock and Tite in Partridge 1981, 326; Cowell and Tite in Partridge 1982, 41
Ditches, Glos	?gold alloys	Trow 1988, 55, fig. 27, 6
Fison Way, Norfolk	Leaded bronze	Linton and Bayley 1982b
Old Sleaford, Lincs	?silver alloys	Heyworth and Wilthew 1987
St. Albans, Herts	Gold/silver; silver/copper; silver; bronze; copper	Richards and Aitken 1959; (Frere 1983, 32)
Sheepen, Essex	Copper/silver; bronze	Moss in Hawkes and Hull 1947, 132
Silchester, Hants	silver/copper/gold	Boon 1954, 69

1.5. Composite metalworking and embellishment

Many Iron Age artifacts were made by combining different metal species different manufacturing processes, namely:

a) Cast and wrought non-ferrous metal components, e.g. cast chapes and embellishments on copper alloy sword scabbard plates (e.g. Sherratt 1983), and cast terminals on gold torcs (Eluère 1987b, 34)
b) Cast copper alloy with iron, for instance swords, linch-pins, bridle-bits, terrets, and mirrors (e.g. Piggott 1950; Fox 1958, fig. 23; Harding 1972, pl. 77, a-c, h-j; Stead 1979; Palk 1984)
c) Wrought copper alloy with iron, for example dagger scabbards (e.g. Jope 1961a), iron fittings on buckets and cauldrons (e.g. Stead and Rigby 1986, 55-9), and copper alloy rivets on spearheads (N. Field pers. comm.).

In addition, non-ferrous metals were also applied to the surface of other metals for decorative effects and other purposes. Iron was occasionally clad with copper alloy sheeting, for example some bridle-bits (e.g. Stead 1979, 47) and pins (Spratling *et al.* 1980, 246-8). Torcs are known to have been made by wrapping gold sheeting around iron cores (Clarke 1954, 38), and very occasionally gold foil or gold alloy coatings were used to decorate copper alloys (MacGregor 1962, 20; Northover 1990; Oddy 1990).

Non-ferrous metal coatings were more commonly applied either by wiping or dipping. Some iron rein-rings for bridle-bits were coated with tin (e.g. Hencken 1938, 71, nos 1 and 2), or with bronze (e.g. Northover 1988, 228), or with bronze over a layer of tin (Spratling 1979, 129). Occasionally, these coating procedures served also to braze on other ferrous components (Spratling 1979, 129; Northover 1990).

Copper alloy artifacts were also coated with tin (Savory 1964 but see Spratling 1966a; Oddy and Bimson 1985; Meeks 1986, 134), and very occasionally with silver alloys (Northover 1990). Some coin copies were plated with silver or gold (Van Arsdell 1989, 55). Pliny, writing in the mid-first century AD, attributes the discovery of the tinning of bronze to mimic silver to the 'Gallic provinces' (*Natural History* IX, 34.162). True gilding is unknown in Britain until the first century AD, and the use of this technique was probably due to Roman influence (Oddy 1990).

Metalwork, in particular bronze, was also embellished with opaque red glass 'enamel', found typically on chariot fittings, brooches, studs, and shield mounts (Bateson 1981, 7-18). Less commonly, metalwork was decorated with coral, for example on brooches (e.g. Stead 1979; Dent 1982, fig. 4), but on a broader range of products on the Continent where its use ceased earlier than in Britain (S. Champion 1985). Other materials which were used occasionally as embellishments include amber, shell, and sandstone and other rocks (Leeds 1933, 56; Stead 1979, 87-8). Metal inlays have occasionally been found (e.g. Bayley 1989, 267).

Metallic joins between different metal species were effected by casting-on (Section 1.4.3), and sometimes by brazing (Wolters 1975; Lang and Hughes 1984; Lang in Stead and Rigby 1986, 388), and soldering (Stead *et al.* 1980, 68).

Indicators of composite working

Evidence for the manufacture of composite metalwork derives largely from the products; rarely has metalworking debris established its occurrence on any site although it may sometimes be inferred from investment mould fragments (Foster 1980, 19). Direct evidence comes from a discarded bronze-clad iron pin and a bronze-coated iron bridle-bit link from Gussage All Saints (Spratling 1979; Spratling *et al.* 1980). At Maiden Castle (Dorset) iron and bronze composite artifacts were manufactured and repaired (Northover 1988, 227-8).

1.6. Comparison of the properties of the metals

The melting points, hardness and tensile strengths of pure metals, and of alloys of composition similar to those used during the Iron Age are compared in Table 1:3. The values given are for modern materials of the nearest composition and production method for which there is data available. In the worked condition, the hardness and strengths quoted are not necessarily the maximum obtainable and, since their sources and means of testing vary, they cannot be too accurately compared. Moreover, values are affected by prior work and heat treatments.

The table shows that for metals in the annealed condition, alloying increases both the hardness and tensile strength. The effects are more marked in steels, gold or silver alloyed with copper, and in tin bronzes with respect to tensile strength only. The

Metal/alloy	Liquidus temperature °C	Hardness HV		Tensile strength N/mm²		Source
		annealed	worked	annealed	worked	
iron	1537	75	-	-	-	a
+ 0.1% C	-	95	195	355	415	b, c
+ 0.25% C	-	132	-	432	494	c
+ 0.4% C	c.1520	160	240	540	600	c
+ 0.6% C	-	210	-	695	770	c
+ 0.9% C	c.1460	-	-	996	-	d, c
+ 0.15% P	-	91	-	-	-	a
+ 0.5% P	-	216	320	-	-	a
+ 1% P	-	250	340	-	-	a
copper	1083	45	115	220	400	e
+ 3% Sn	c.1070	69	196	324	633	c
+ 5% Sn	c.1050	75	212	340	710	c
+ 7% Sn	c.1040	86	234	355	741	c
+ 10% Sn	c.1020	90	250	-	-	e
+ 10% Sn + 5% Pb	-	70	-	185	231	c
+ 10% Zn	c.1075	60	150	278	510	b
+ 30% Zn	c. 980	65	185	324	695	b
+ 10% Sn + 2% Zn	-	85	-	280	-	b, c
+ 5% Sn + 5% Zn + 5% Pb	-	65	-	200	-	c
silver	962	26	90	140	386	c
+ 7.5% Cu	779	60	150	225	420	d, c
gold	1064	25	58	151	216	f
+ 25% Ag	1037	32	98	185	336	f
+ 8.3% Cu	951	66	160	474	850	f
+ 25% Cu	900	115	210	514	874	f
+ 25% Cu/Ag (1:1)	905	110	190	480	837	f
tin	232	5	-	15	-	d, b
lead	327	4	-	17	-	g, b

Values are for the purest metals and alloys, and where possible for bar or rod in similar condition for each group of metals, generally in the cold-rolled condition for worked values. Worked values are not necessarily the maximum obtainable.
Hardness values: some converted from Brinell or Rockwell scales. Loads where stated = 10-500kg.

Sources:

a Tylecote and Gilmour 1986
b Higgins 1973
c Metals Reference Handbook. Smithells, C. J., 1967, (4th edn). Butterworths
d Metals Handbook. 1961, (8th edn). American Society for Metals
e West 1979
f Smith 1933
g Smithells Metals Reference Handbook. Brandes, E. A. (ed.), 1983, (6th edn). Butterworths

Table 1:3 Physical properties of selected modern metals and alloys addition of tin to copper has a greater effect in hardness and tensile strength than an equivalent addition of zinc in copper. The addition of lead to copper alloys reduces both the hardness and tensile strength. In the cold-worked condition the effects are greater, particularly in tin bronzes, and gold or silver alloyed with copper. Alloying also lowers the melting points commensurate with the nature and proportion of the phases formed.

The presence of impurities normally present in archaeological metals may have a similar marked effect on the properties. This is well demonstrated in iron, in which phosphorus dramatically increases the hardness, even in the annealed condition (Tylecote and Gilmour 1986, 9, table 2).

Since bronze and iron appear to have been the most commonly employed metals in the Iron Age, their hardness and tensile strengths are further compared in Figure 1:8, in relation to the tin content in bronzes, and carbon content in irons/steels. The very low hardness of annealed bronzes compared with work-hardened bronzes and steels is demonstrated, and also the considerable hardness obtained by the quenching of steels (Fig. 1:8a). The tensile strength of steels is shown to increase linearly and exceed the strength of bronzes (Fig. 1:8b).

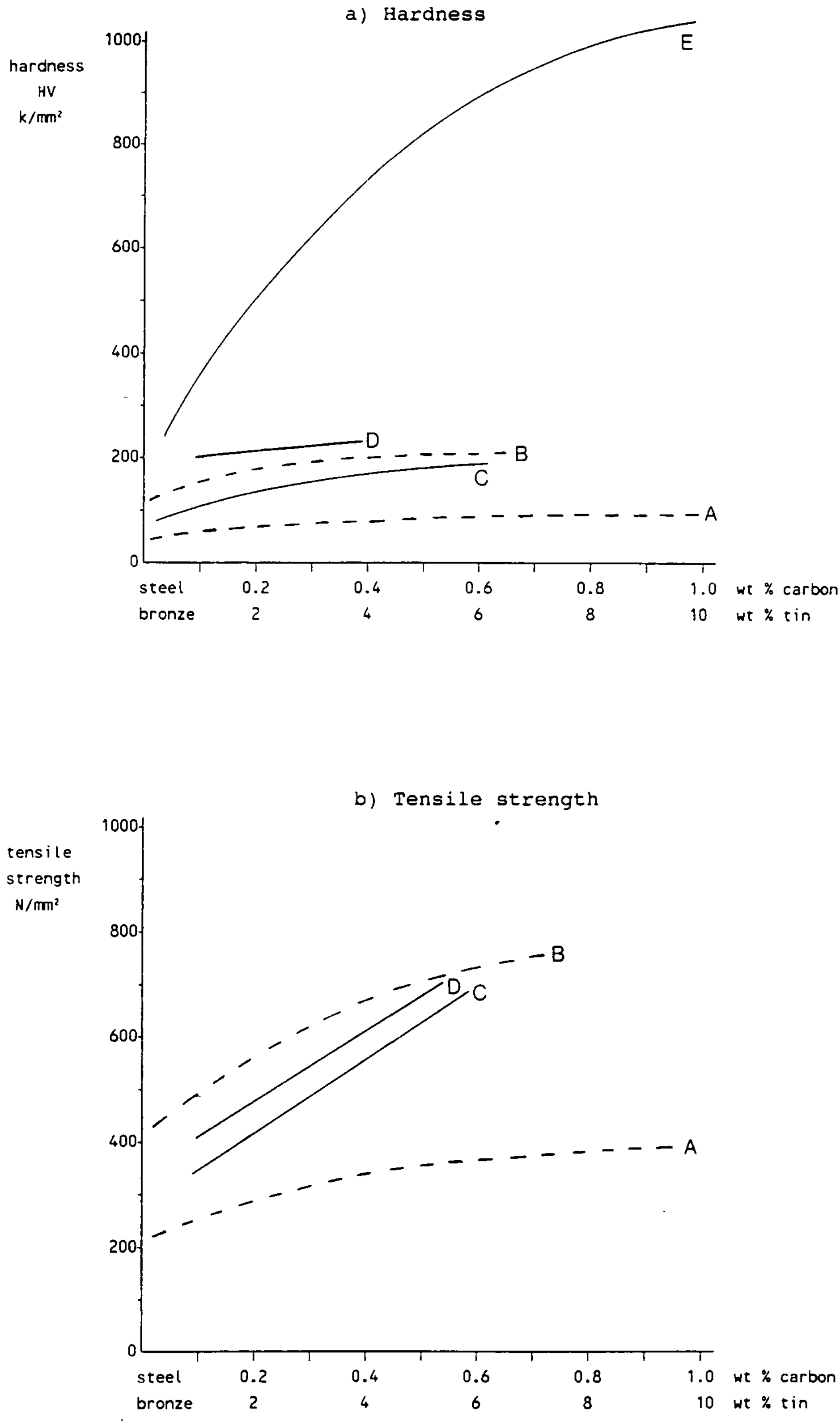
1.7. <u>Selection of metals and alloys during the Iron Age</u>

During the Iron Age, metals may have been selected, and alloyed, for a variety of different and possibly interrelated reasons. Technological factors are discussed earlier in this Chapter; this Section summarises the possible main factors which may have determined the use of a particular metal or alloy, under the following five topics:

(1) Working properties during manufacture
(2) Enhancement in properties in the finished product
(3) Other technological factors
(4) Economy
(5) Social, political, and other factors.

(1) <u>Working properties</u> (during manufacture)
The advantages of hot-forging of metals are greater plasticity, freedom from work-hardening, and in iron the ability to be welded without detrimental effects.

The advantages of alloying seem to be the lowering of melting



A = Bronzes annealed B = Bronzes worked
C = Steels annealed D = Steels worked E = Steels quenched
Soures: as for Table 1:1, with additions from Samuels 1980, fig. 90.12

Figure 1:8 Comparison of hardness and tensile strength in steels and bronzes points, and increased fluidity during casting. Alloying produces a metal which is less easily worked; there appears, therefore, to be no mechanical advantage in alloys which are for wrought manufacture. Nevertheless, the lower working temperatures of alloys presumably facilitated the casting of non-ferrous metals into ingots prior to wrought working, and the annealing of alloys. Steels can be forged and welded at a lower temperature than iron.

(2) Enhancement of properties (in the finished product)
The principal effects of alloying are alterations in toughness, and enhancements in hardness and strength.

(3) Other technological factors
Local availability of metal or raw materials (including fuel), and tools, may have been significant in the employment of a particular metal species or alloy.

(4) Economy
Economy may have been important in the use of any one metal species, or of a particular alloy composition, for example the addition of lead to bronze at concentrations greater than 2% lead. Economy of fuel may have had some significance concerning the lower temperatures required for non-ferrous metalworking, and in particular when alloyed. It has been estimated that copper ores require at least twice, and perhaps three or four times the amount of fuel to produce finished artifacts, compared with iron ores (Horne 1982).

(5) Social, political, and other factors
Colour or lustre of metal, skills, traditions or other 'cultural' reasons may have determined the use of a certain metal or alloy. Alterations in styles of artifacts may have enabled different techniques or metals to be used (Bayley 1985b; 1990). Supply of metal, including shortages inferred from the hoarding of bronze during the earliest part of the Iron Age (Bradley 1982; 1987) and of iron during the later Iron Age (Manning 1972), for whatever reason, presumably affected the employment of certain metal species.

The restricted use of gold and silver (Haselgrove 1987; Trow 1988), and brass (Bayley 1990), suggests that these metals were under official control. Good-quality iron ores, or the products, may also have been under monopoly control (Alexander 1981, 64).

1.8. <u>Qualities sought in metalworking tools</u>

By empirical observation, the Iron Age metalworkers would presumably have selected the tools appropriate for the technique used, modified the tools, or employed different techniques or methods of working if suitable tools were unavailable. Iron tools may have been deemed 'good' or 'useless' - qualities bestowed by prior ownership, magical powers, or other elements. Nevertheless, experienced metalworkers, those who would have used numerous different tools, were likely to have realised that their skills were enhanced by tools made by certain iron-workers, iron from certain sources, or that the tools could be improved by altering their form or metal structure.

From present knowledge, some generalisations which may be relevant to the use of tools during the Iron Age may be deduced from working properties and characteristics of materials.

For metal tools in general, the qualities sought in the metal are plasticity, durability and, for cutting tools the ability to acquire and maintain an edge (Thålin-Bergman 1979, 99). These qualities are more commonly expressed as the physical properties of hardness, strength, and toughness (e.g. Smith 1965; Coghlan 1977; Pleiner 1980; Tylecote and Gilmour 1986).

In metalworking tools, the desirable qualities are relative to the type and condition of the metal, and depend on the technique employed and the method of working. These are interdependent factors, and ones which affect the ease of working and the efficiency of the procedure. The properties and conditions are discussed under nine topics below.

(1) <u>Hardness</u>

The pre-requisite of cutting tools (e.g. cold chisels, gravers, files, and scrapers), is generally that the edge must be significantly harder than the metal being cut. For <u>hard</u> metals, an additional hardness over the work-piece of about 150HV is required (R. Hamby pers. comm.). Without a proportionate difference in hardness, the tool fails to bite and skids across the surface of the work-piece. For softer metals, the difference in required hardness may not be as great.

Tools which deform metals (e.g. hammers, punches, dies) similarly require a proportionate hardness (depending on their precise function) in order to prevent undue damage to the tool. If a tool and work-piece are of similar hardness both will deform during work, but nevertheless some limited work may be possible.

(2) Durability (wear resistance)
Durability, a function of both toughness and hardness, determines the life of a tool before the need to reshape or grind.

(3) Edge maintenance
The condition of the working edge may determine efficiency of the procedure, particularly in cutting tools such as cold chisels.

In experiments with gravers made from bronze of various compositions, Maryon demonstrated that only bronze containing at least 20% tin was hard enough to engrave copper, though the tool edge did not survive very much work and the tool marks degraded as the edges of the tools blunted or splintered (Maryon 1949, 117-8).

For some types of tools it is essential that the working edge is not damaged in order that the work-piece does not become disfigured; included in this category are coin dies, decorating tools, and some finishing tools (e.g. planishing hammers and burnishers).

(4) Strength
Tools need to be strong to survive the working stresses. In this respect, materials such as wood, bone and antler, although of low hardness and tensile strength compared with metals (cf. Samuels 1988, table 3.1), have complex structures and are able to survive a relatively large amount of compression, particularly antler (MacGregor 1985, 25-9).

(5) Toughness
Toughness determines the force which may be applied (especially in struck tools) before fracture or bending.

(6) Type and condition of metal
Individual characteristics of metals and alloys, the thickness of metal, temperature of working, and the degree of work-hardening, affect the ease of working. For example, relatively pure gold and silver, being extremely soft and malleable, may be worked with tools made of virtually any material providing that a very sharp tool mark (e.g. from a die) is not required (Ogden 1982). Furthermore, since thin and soft sheet metal is readily deformed, techniques such as raising,

sinking, and *repoussage* can be effected by tools made of hard (compact) wood, bone and antler (Untracht 1982).

(7) Force

Force (mass x acceleration) applied may determine the amount of work attained; in struck tools in particular, the weight of the tool (often the hammer), and speed and distance of blow control the impact force (Untracht 1982, 246).

(8) Technique

The stresses or acting forces (Samuels 1988, 60) involved which enable the working of the metal (strain) differ according to technique. Techniques such as drawing-down, upsetting, raising and chasing, involve squeezing the metal (compressive stresses), whereas techniques such as sinking and *repoussage* involve stretching the metal (tensile stresses). Planishing and pressing utilise a combination of compressive and tensile stresses (Higgins 1973; Loyen 1980). Cutting involves a shearing action which is a function of opposing and unaligned forces (tension, compression, or both) which result in fracture (Samuels 1988, 79-80).

Figure 1:9 shows the effects of stress during working. This stress/strain (or force/work) curve is for a metal stressed in tension (Samuels 1988, fig. 3.2). The behaviour of a metal stressed in compression is similar; the elastic and plastic deformation ranges are comparable, as also is the rate of work-hardening during normal working, but the maximum strain before fracture is greater during compression (Samuels 1988, 78).

(9) Method of working

Some techniques require close control of the work and are therefore only used on cold metal, for example engraving, raising, sinking, and *repoussage*. The latter three techniques result in considerable work-hardening of the metal since they deform and displace the metal. Sheet metal is apparently more readily formed into a vessel by sinking than by raising (Maryon 1944).

Some metalworking tools today are made deliberately from soft materials (e.g. wooden, and leather mallets) so that the tool damages preferentially to the work-piece, and the latter is not marked (Untracht 1982, 248).

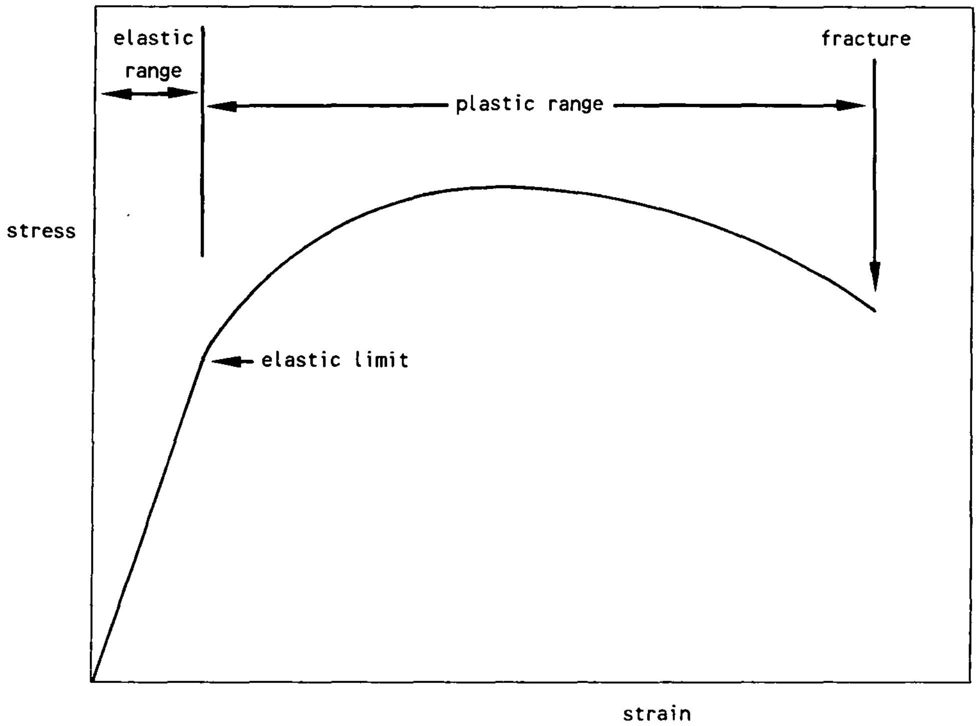


Figure 1:9 Diagram showing the effects of stress on metal

(After Samuels 1988, fig. 3.2)

In summary, the qualities sought in metalworking tools thus depend principally on the techniques employed, the method of working, and the nature and temperature of the work-piece. Tools intended to cut metal or to effect substantial displacement of metal ideally require a combination of several different physical properties (depending on their precise function), which include: relative hardness, durability, the ability to take and maintain an edge, strength, and toughness.

From present knowledge, some generalisations may be made regarding special requirements in metal tools according to the metal species (of the work-piece and the tools) and the working temperature. Alterations in selected physical properties according to temperature are shown in Figure 1:10. Increase in ductility (or malleability), and reduction in hardness are the most significant effects during hot-working. Brittleness in certain metals, at ambient or elevated temperatures, may also limit the use of these metals for certain functions or procedures.

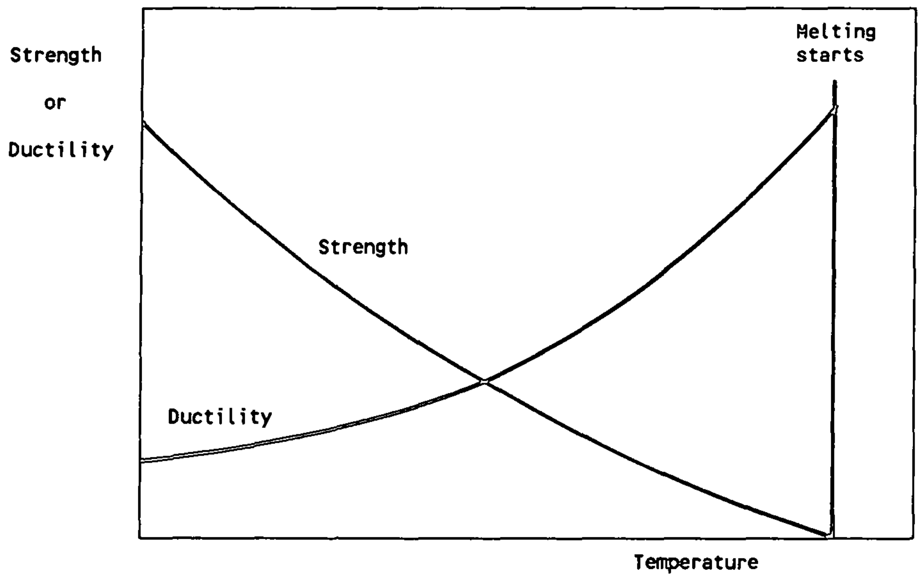
As discussed earlier, during the Iron Age, iron was forged in the hot condition though occasionally cold-worked, whereas non-ferrous metals were probably usually worked in the cold condition, with the possible exception of coin striking.

Metals are soft and become increasingly malleable as temperatures increase (Figure 1:10) and are then very readily worked (Samuels 1988, 114). Thus, tools made of iron or copper should function perfectly well during hot-forging, with the possible exception of certain copper alloys which are brittle at high temperatures (Section 1.4.4).

In the cold annealed state, ferritic iron is soft (Table 1:3); it should therefore be possible to shape or mark iron with a hardened iron or bronze tool, given the proportionate difference in hardness (Figure 1:8). The cold-working of iron during the Iron Age was probably normally limited to finishing, decorating, and special forming operations (such as the making of saws and files), and these procedures were likely to have required tools with hard and durable edges. The data in Table 1:3 and Figure 1:8 suggest that the cold-working of steel or phosphoric iron could present considerable problems if precise work is involved - unless the tools available are hardened, or damage to the tool is acceptable.

Non-ferrous metals in the annealed condition are relatively soft

a) Typical alteration in strength and ductility with increasing temperature



b) Variation in hardness with annealing temperature (shown for a low-carbon steel)

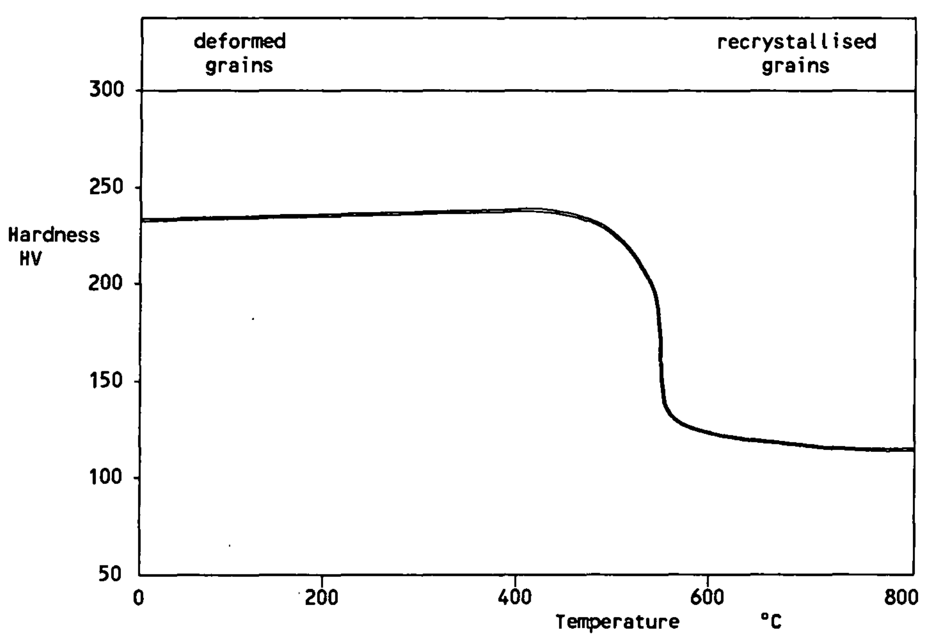


Figure 1:10 Diagrams showing the effects of temperature on selected properties of metals

After Samuels 1988, figs 4.5A and 9.17

(Table 1:3) and probably therefore can be cut or forged with tools which are not of extreme hardness (e.g. tools of steel, phosphoric iron, or work-hardened bronze). However, cutting tools in particular require toughness and edge maintenance, and these qualities are lacking in severely work-hardened metals, phosphoric irons, and severely quenched and untempered steels, all of which are very brittle.

A useful comparison of forging and cutting tools may possibly be gauged from earlier tools. Measured hardnesses for Late Bronze Age work-hardened tools in the normal tin range (below 15%) are typically 200-220 HV, but above this the bronze is too brittle for edge tools such as chisels, though some non-edge tools do reach *c*. 300 HV (P. Northover pers. comm.). Analyses of five Late Bronze Age socketed hammers have shown tin contents between 9% and 22% (Brown and Blin-Stoyle 1959, nos 17, 32, 128, and 142; Northover 1982, table 1, no. 128), which, from comparative data (cf. Coghlan 1975, 81-3; Tylecote 1986, tables 19 and 61), suggests a hardness range of 70-260 HV in the as-cast condition, but *c*. 200-300 HV if homogenised and severely work-hardened (deliberately or through use).

The requirements sought in some modern hand tools are shown in Table 1:4. Although these examples are manufactured from carbon or alloy steels and by techniques unavailable to the Iron Age metalworker, they serve to indicate the special properties desirable in individual types of tools, and the differences between tools for hot-work and cold-work.

Tool	Special requirements	Hardness HV	
Hammers	Hardness; toughness	650-830	520-660*
Swages	Toughness; hardness; wear resistance	450-740	
Mandrels	Hardness; resistance to abrasion	650-830	
Hot chisels	Extreme toughness; red hardness	470-630	
Cold chisels	Extreme toughness; edge maintenance	510-700	
File-cutting chisels	Wear resistance; keen edge	770-860	
Engraving chisels	Hard, keen edge	650-830	
Hot punches	Hot hardness; wear resistance	390-600	
Cold punches	Hardness; wear resistance	650-830	
Files	Extreme hard surface; tough core	650-830	870-910#
Scrapers	Very high hardness; retention of keen edge	650-830	
Draw-plates for wire	Hard surface; resistance to abrasion	650-800	

Hardness. The hardness values in column 3 are derived from tables which relate the usual working hardness range of the preferred carbon or alloy steel for the type of tool under consideration. The range indicated may therefore be broader than the desired hardness for the type of tool and this would normally be adjusted, in conjunction with increased toughness, by correct tempering.

Sources: Wilson 1975, 315-25, 346-65 (columns 2 and 3)

* British Standard 876:1981, 1 (converted from Rockwell C scale)

\# Carr 1969, 16 (specifically for metalworking files)

Table 1:4 Desirable properties of some modern tools

CHAPTER 2

THE STUDY OF METALWORKING PROCESSES, TECHNIQUES AND TOOLS

2.1. Introduction

The study of artifacts beyond simple classification requires assessment of their use and social meaning (Rowlands 1971; Klejn 1982; Foxon 1982). 'Use' encompasses action and function; 'meaning' reflects social use and involves intention, purpose, and symbol (Foxon 1982). Tools are a special category of artifacts being mid-way in a production cycle, and as a consequence, they may have had special significance in both production and in symbolic use.

This chapter examines the various approaches which are used to analyse metalworking, in particular ferrous processes since the present study is concerned principally with tools made of iron.

Section 2.2 considers some of the social aspects of metalworking, and the methods of assessing metalworking, metalwork, and tools in these terms. Section 2.3 outlines the various methods by which ironworking processes and ferrous artifacts are analysed. Methods pertinent to the analytical procedure of the present study are discussed in greater detail, namely typological and functional analysis, conservation, and metallography. The other methods mentioned are relevant to the interpretation of functional associations of the tools, or offer possibilities of provenancing and dating of ferrous tools. Factors which affect the identification and characterisation of ferrous metalworking tools are discussed in Section 2.4. The analytical procedure of the present study is given in Section 2.6.

2.2. Social and industrial aspects of metalworking

2.2.1. Organisation of metalworking

Production systems, at least in the later Iron Age, were concerned principally with agriculture, and specialisation in crafts for local consumption or industrial production for dispersal (Cunliffe 1978; 1984a). In prehistoric terms, industry is defined by Alexander as 'production on too large a scale for personal needs' (Alexander 1972, 845). Rowlands employs a similar definition of industry for the Middle Bronze Age:

> 'any form of productive work that is carried out as a specialist activity (whether full-time or part-time) by an individual or group of individuals' (Rowlands 1976, 115).

Rowlands emphasises the degree of skill required and the likelihood of it representing specialist activity, as opposed to the limited skills required for domestic crafts (Rowlands 1976, 115).

It has been suggested that the more complex metalworking activities during the Iron Age may have been organised by distinct social groups, families, or 'clans' (Spratling 1972; 1979; Megaw 1985). Supply of ore or metal and the distribution of products may have been controlled by patronage or a social elite (Saunders 1977; Alexander 1981; Bradley 1984). Skills, techniques, and innovations may have been transferred by direct social contact (Megaw 1982), also tools or at least their methods of manufacture (Collis 1977), or the patronage may have had strict control (Harding 1974; 1977). As Fitzpatrick (1984) has pointed out, the two are not necessarily incompatible. A two-level social system of ironworking has been suggested by Alexander: high 'prestige' regional industries based on superior ores or skills and producing trade items, and low 'prestige' working based on local trade of ore or blooms and serving local needs (Alexander 1981).

2.2.2. Assessing metalworking techniques and skills

The material evidence for the principal manufacturing processes employed during the Iron Age is examined in Chapter 1, together with the possible factors involved in the selection of the metals. The individual metalworking <u>techniques</u> which were used may sometimes be assessed from the following: structural form of products, tool marks, tools, blanks, semi-finished products and failures, off-cuts, and residues. The techniques employed may have depended on a number of interrelated factors including:

(1) Materials available
(2) Type of product and demand
(3) Suitability of the tools available
(4) Learnt techniques and skills
(5) Experience of the individual metalworker
(6) 'Cultural' factors and practices.

The nature and composition of the surviving products may in some cases be determined by scientific examination. Tools may also be analysed, and inferences may be made regarding the suitability of those individual tools for their function.

Skill, a function of both learning and experience, is dependent on a high level of manual coordination and the ability to control the tools effectively (Untracht 1982, 26). Skill, or lack of skill, may sometimes be gauged by comparison of artifacts within the archaeological record (e.g. Spratling 1970c,). However, these perceived skills do not necessarily take into account the range of tools available to the individual metalworker (which could affect the type and level of work performed), nor the qualities necessarily sought in the Iron Age (Megaw and Megaw 1989, 19). Social and cultural factors are not easily isolated or defined; in metalworking they are often interrelated with technology (Rowlands 1976, 186-7).

Ethnographic sources sometimes offer suitable models providing these are interpreted within the framework of the archaeological data (Rowlands 1971, 210). Ethnology may give useful insight into different technologies and traditions (e.g. Rowlands 1971), but is more appropriate in examining social structures and the organisation of metalworking in general terms, rather than specific factors such as skill and the use of tools, since these are culturally dependent (Deetz 1977, 11).

Classical sources are of little assistance for the British Iron Age, and in any case do not define social aspects of craft working (Alexander 1981).

2.2.3. Assessing purpose and use of tools

The purpose and use of tools may sometimes be inferred from the artifacts, their context and associations, or through analogy. Functional use and symbolic use are considered separately below.

I. Functional use

(a) <u>Artifacts</u>

Tools, at least in their original concept (contra symbolic use), are devised for utilitarian purposes. In general, therefore, their attributes reflect their intended purpose and the method of use (Goodman 1964). Moreover, tools are usually devoid of decorative or other attributes superfluous to their function, though there are exceptions.

Classification and typological study of artifacts is traditionally concerned with morphological attributes, excluding technology and use (Klejn 1982, 79). One objection to functional classification is that division is based on culturally orientated assumptions (Rowlands 1971, 210; Klejn 1982, 7; Foxon 1982; Hingley 1984, 73).

For metal artifacts, Rowlands advocates that regional and chronological differences should 'be related primarily to the industrial organisation that produced them' (Rowlands 1971, 221). Other writers stress the need to consider the social context in which artifacts were made and used (e.g. Hill and Evans 1972; Spratling 1972; Hodder 1977; Klejn 1982; Foxon 1982), and the requirement of functional related objectives in typological analysis (e.g. Clarke 1968; Hole 1973; Cunliffe 1983).

The relatively unchanged forms in basic types of ferrous metalworking tools have been remarked upon on several occasions (e.g. Manning 1969; Spratling 1972; Saunders 1977; Megaw 1985; Stead 1985b). According to Saunders, this should facilitate comparative functional study (Saunders 1977, 18). Manning, referring specifically to metalworking tools, states:

> 'Specialisation demands more tools, each designed to do a rather more limited range of work more efficiently than is possible with a single, more basic type.' (Manning 1981, 53).

To demonstrate changes in metalworking tools over time it should therefore be necessary to consider function and use, morphology including regional variations, and where possible also technology (cf. Rowlands 1976, 184-7). Typological study should take into account the purpose of the tools, otherwise inappropriate conclusions may be drawn. For example, chronological development has been suggested from the morphology of early ferrous metalworking tools from smiths' graves in Europe (Kokowski 1981), ignoring differences in function of individual tools.

The difficulties in dating ferrous tools from the Iron Age and Roman periods which lack external dating evidence, and thus the determination of tool introductions, is stressed by Manning (1969, 17-21).

(b) Analogy

Classical sources and depictions give little useful insight into techniques, though they do sometimes assist interpretation of the range of Roman tools which were available and the crafts for which they were used (e.g. Manning 1969; Rees 1979; Gaitzsch 1980). In this respect, classical sources may have some relevance to tools from the final century of the British Iron Age.

Ethnographic and other modern and recent sources may sometimes be useful for the interpretation of tools providing the techniques can be demonstrated to have probably been employed during the Iron Age.

(c) Tool marks

By analogy with modern workshop practice, the study of tool marks may suggest the possible techniques employed, and the types of tools which were used. However, the precise methods by which the tools were used remains conjectural. Tool marks are sometimes found on part-manufactured items, but are less common on finished products since these were often obliterated by wear, or were intentionally removed unless applied for decorative purposes.

Ambiguities in the interpretation of tool marks are common. Semantic difficulties may arise in the naming of a tool from its form as opposed to function (Lowery *et al.* 1971, 172), and over the description of the tool and the tool mark (e.g. width of tool edge producing the longer dimension of the tool mark).

(d) Experimental reconstruction

Experimental reconstructions may assist in understanding the use of tools and techniques, providing these are conducted within accepted experimental limits (Coles 1976, 46-8). However, as Coles has pointed out, even if a particular tool can be demonstrated to function successfully, it does not necessarily mean that the tool was used in the manner tried, nor for the purpose for which it was employed in the experiment (Coles 1979, 47).

II. Symbolic use

> 'Much of our most informative ironwork comes from hoards, burials, or votive deposits, contexts which themselves are by no means common' (Saunders 1977, 18).

Symbolic use of tools is less readily determined than functional use. Some examples of possible ritual and other symbolic uses of tools, and symbolic connections of metalworking, are given below.

Presumed ritual (or votive) deposits of tools for various crafts are known from the Bronze Age and earlier Iron Age (Bradley 1982; 1984; 1987; 1988) and the later Iron Age (Manning 1972; 1980; Bradley 1987), many of which are associated with watery contexts. The content and context of hoards requires careful scrutiny before ritual deposition may be assigned (Bradley 1982), and cultural and regional variations are possible (Bradley 1984, 166). Wait has identified regional traditions in the deposition of metalwork in watery contexts in the Iron Age, though tools are not included as a specific category of artifacts (Wait 1985).

In burials, high-status metalwork is frequently interpreted to signify rank (e.g. Bradley 1982). Deposits of metalwork in rivers may have been substitutes for burials (Jope 1961a, 321; Bradley 1982), with weapons symbolic of power, and tools symbolic of production (Bradley 1982). Tools deposited in burials and other contexts may therefore have special significance in the breaking of the production cycle (Bradley 1982, 117; Gosden 1989, 378).

Copies of tools in diminutive form are known in bronze from the earlier Iron Age (C. Gingell pers. comm.) and the later Iron Age (e.g. Bulleid and Gray 1953, E74; Stead 1979, 84; Spratling 1972, nos 330-332), some of which may have been pendants or charms (Stead 1979; cf. Bradley 1987). It seems very possible that full-size tools may have been made specifically for symbolic or other reasons. Evidence of use (i.e. wear) need not exclude symbolic significance in use or in deposition, nor does negative evidence of wear indicate a non-functional purpose.

Representations in Iron Age art on metalwork include animals, frequently mythical, and the human head - presumed to be symbolic (Green 1989; Megaw and Megaw 1989).

Depictions from the Roman period frequently include tools on stonework, pottery, and metalwork. The hammer, tongs and anvil were used as representations, possibly of metalworking, the metalworker or owner of the tools, or symbolically of the 'smith god' (Leach 1962; Goodman 1964; Gaitzsch 1980; Manning 1985).

Classical sources suggest magical associations for the transmutation of ore to metal, metal to artifact, and the regenerative properties of minerals and metals (e.g. Pliny *Natural History* IX, 33 and 34; Dioscorides *Herbal* V, 89-101). Similar 'supernatural' powers may have been attributed to specialist metalworkers such as those making weapons (Alexander 1981, 65).

Eighth century AD Irish sources suggest that the blacksmith was attributed with magical-religious status; the hearth (or the fire) with regeneration; and iron with truth (Scott 1987). Ethnographic sources suggest that great esteem may sometimes be placed on tools (Rowlands 1971, 217; Gosden 1989, 364).

Recent sources and traditions in Europe indicate that tools may sometimes be objects of esteem, privilege, representations and symbols (Heine 1988). Frequently tools are owned and used by only one craftsman, principally because tools are altered to suit an individual's needs and methods of use (Lowery *et al.* 1971; Heine 1988). This 'attachment' which is recognised in modern crafts may also have been prevalent during the Iron Age and may therefore have been connected with the occurrence of tools in burials and ritual deposits.

2.3. Approaches to the study of iron and ironworking

2.3.1. Typological and functional analysis

Traditionally, studies of Iron Age ironwork have concentrated on artifacts of wealth and display (Manning 1969, 16), and have aimed to chronologically sequence the artifacts through stylistic affinities. Only secondarily have artifacts been interpreted in terms of industry and economy of settlement (contra Cunliffe 1983).

The study of ironwork is hindered by corrosion effects. X-radiography now enables rapid screening of ironwork, and suitable bench units have been readily available since the late 1960's. Nevertheless, lack of resources has not always enabled adequate treatment of ironwork and study has often been limited to the more easily identifiable, complete, decorated, or complex artifacts. This has led to an incomplete and biased record, with many assemblages interpreted from a restricted range of comparative examples. The miscellaneous iron artifacts, such as those once described as 'junk iron' (Hencken 1938, 71), still seldom receive their due attention despite these probably forming the bulk of the ironwork from many occupation sites, and comprising artifacts relevant to the interpretation of industry and economy.

Surveys of specific categories of Iron Age artifacts have tended to concentrate on distribution patterns and chronology, for example swords (Piggott 1950), daggers (Jope 1961a), currency bars (Allen 1967), firedogs (Piggott 1971), agricultural implements (Rees 1979), and bridle-bits (Palk 1984). A more analytical approach in terms of technology and manufacture, or use, is adopted in studies of axes (Manning and Saunders 1972; Scott 1974a), swords (e.g. Stead *et al.* 1980), cauldron chains (Manning 1983), metalworking tools (Rodwell 1976; Saunders 1977; Manning 1980), and ironwork from the later Iron Age and Roman periods (Manning 1969; 1985). Social use of iron is discussed for hoards of ironwork (Manning 1972) and for currency bars (R. Hingley forthcoming).

2.3.2. Stylistic analysis

The study of art styles, usually in conjunction with typological analysis, may assist the chronological sequencing of artifacts, and sometimes may suggest regions of manufacture, exchange, repair of artifacts, and symbolic influences (e.g. Spratling 1972; Stead 1984a; Megaw and Megaw 1989, 20).

On the Continent, much of the early, datable and decorated metalwork occurs in rich graves, whereas in Britain, the majority of decorated artifacts lack associations, being principally chance finds from watery contexts (Jope 1961a; Megaw and Megaw 1989). The interpretation of earlier British art styles therefore relies substantially on continental affinities (e.g. Jacobsthal 1944; De Navarro 1972), for which a La Tène sequence is appropriated: La Tène I, 450 - 250 BC; La Tène II, 250 - 120 BC; La Tène III, 120 BC - AD 1 (de Navarro 1936; Stead 1985a, table II; Megaw and Megaw 1989, 258).

Analysis of British art styles is based principally on non-ferrous metalwork owing to better survival than iron (and organic materials), and because pottery was normally less elaborately decorated. The principal surveys of British styles include: Leeds (1933), Fox (1958), Megaw (1970), Spratling (1972), MacGregor (1976), Stead (1985b), Megaw and Megaw (1989).

2.3.3. Conservation

Conservation encompasses the archaeological recovery and immediate care of artifacts, their examination and analysis, and long-term preservation. Currently, emphasis is given to passive storage and to selective investigative conservation (Biek 1963; Cronyn 1990, 8-13).

The principal aid to the examination of ironwork is X-radiography, which can enable identification, reveal morphological and technological information, and may also suggest the presence of associated materials such as mineralised organic remains and non-ferrous metals (Scott 1974c; Corfield 1982; Cronyn 1990, 188-191). In addition, the condition of an artifact may be determined, which is important for assessing future storage and treatment, and integrity prior to metallographic sampling. Other radiographic techniques are occasionally used on ironwork, for example Xero-radiography (J. Lang pers. comm.), micro-X-radiography (S. O'Connor pers. comm.), and gamma- and neutron radiography (Corfield 1982).

Early conservation treatments, such as electrolytic and chemical stripping, aimed to stabilise ironwork by removing accretions and corroded layers entirely (e.g. Plenderleith and Werner 1971). These methods considerably damaged the artifacts and often left few features diagnostic of identity; artifacts without metallic cores did not survive. Moreover, some assemblages of iron were then dressed with thick and opaque coatings in order to simulate a 'natural' appearance for display purposes (Western 1972). Not only are such coatings now considered aesthetically unacceptable, but they obscure and disguise typological information.

Nevertheless, a number of ironwork assemblages, such as those from Glastonbury and the Meare lake villages, were not treated so drastically, and furthermore, are available for study in a relatively similar condition to when they were originally described. The following account describes the treatment given to iron finds from Glastonbury (Bulleid and Gray 1917):

> 'Some of the iron specimens occupied several hours in cleaning and then the greatest care was necessary to avoid breaking them in the process. It was no exaggeration to say that sometimes objects of iron were on discovery twice and even three times their original dimensions, owing to the enormous accumulation of rust, causing a proportionate weakening of the true metal... In some cases the oxidation was so great that it was at first impossible to define the true outline of the original object, but, with perseverance and much care in removing rust only and avoiding the comparatively soft "core", we were often rewarded by a fair example of a knife, bill-hook, adze or other tool.... frequently it was found that a very small nondescript fragment of iron had expanded ... to the size of a hen's egg....' (Bulleid and Gray 1917, 362-3).

The account is reproduced here because of the historical significance in relation to the numbers of artifacts from excavations by Bulleid and Gray (Bulleid and Gray 1917, 360-392; Gray and Bulleid 1953, 233-248; Coles 1987, 117-27) which are incorporated in this study, and it is fortunate that their approach was sympathetic to the artifacts.

Today, sensitive methods are used to remove accretions (if these are removed at all), and the often fragile 'original surface' and any associated material is preserved *in situ*. However, satisfactory methods for the stabilisation of archaeological iron are not yet available.

The nature of iron corrosion processes are varied, depending not only on the burial environment in regard to pH, oxygen potential, ionic concentrations, and microbial activity, but also on the composition of the artifact in terms of electrolytic reactions between structural phases of the iron, interfaces, stressed regions, and associated non-ferrous metals and other materials (Cronyn 1989, 18-19, 179-88). Analyses of corrosion products have assisted our understanding of corrosion effects (e.g. Turgoose 1982; 1985; Knight 1990), and such projects have aimed principally to develop new methods for the stabilisation of ironwork.

Volume expansions during corrosion, namely the volume/mass ratios of corrosion products compared with metallic iron, present difficulties in typological interpretation. For example, the volume increase for the two most common corrosion products of iron are x2.6 to x3.8 for geothite, and x2.0 for magnetite (Watkinson 1983, table 1). Unusual and often confusing effects of corrosion caution of ambiguities in morphological interpretation (e.g. Biek 1979, 75-7).

2.3.4. Scientific analysis

The principal scientific methods which have been applied to iron have examined technology, provenancing, dating, and corrosion effects (discussed above). Often programmes of analysis have involved more than one aspect of research, and frequently have combined the study of artifacts and by-products.

(a) <u>Metallography</u>

Metallographic examination may reveal information on the composition of artifacts and techniques used in their manufacture, in particular construction, forging, welding, hardening, and heat-treatments (Scott 1974c). By comparison of artifacts within and between chronologically and culturally related assemblages, inferences may be made regarding the level of technology applied to particular types of artifacts. In a broader context, technological development of iron may be investigated.

The study of ferrous technology has been much advanced on the Continent through systematic studies of a broad range of artifacts from Hallstatt, Iron Age, and later assemblages. Smithing techniques and functions of artifacts have been correlated with the characteristics of bloomery iron and steel (e.g. Piaskowski 1961; Pleiner 1962; 1982). In Britain, studies have been undertaken only on a limited range of artifacts and from a small number of assemblages, and not uncommonly analysis and interpretation is less thorough than on the Continent (cf. Piaskowski 1987; Pleiner 1987)

Metal samples are ideally removed from areas of an artifact which were likely to have been submitted to different smithing techniques and heat-treatments, for example both from the working edge of a tool and from the tang or stem. Owing to the heterogeneity of bloomery iron, the metal structure may vary over small distances or even between grains. A single small sample may not, therefore, be representative of the composition of the whole artifact, nor necessarily of the region selected for examination.

Residual metal structure may be preserved within the corroded layers of an artifact. These 'relic' or 'remanent' structures were first noted by Knox (1962), and have been studied subsequently by Scott (1983; 1989) and Nosek and Mazur (1987) in particular. Residual metal structures can yield valuable additional information to that which may be visible in the metal of a section, for example a carbon gradient suggesting surface carburization. Furthermore, when an object appears to be totally corroded in the area of interest, or if the item is too fragile to allow the removal of a metal sample, flakes of corrosion products may be sampled. However, caution is needed in interpreting residual structures since some constituents may be preferentially corroded. In particular, martensite seldom survives (Nosek and Mazur 1987; Scott 1989). Moreover, volume changes due to corrosion may disrupt the relationship of the constituents, rendering qualitative estimation of phases (e.g. pearlite) impossible.

Technological examination of ferrous artifacts is sometimes combined with quantitative elemental analysis, either to resolve metallurgical aspects (e.g. Tylecote and Thomsen 1973; Tylecote 1990), or to attempt provenancing of artifacts (e.g. Ehrenreich 1985).

The Iron Age artifacts from England and Wales which have been examined either for metal structure and technology, or for elemental composition and provenancing are listed under site in Table 2:1. A number of the artifacts sampled are of uncertain identity: this applies in particular to fragmentary blades and rods, and to some of the artifacts which were sampled before, or instead of, X-radiographic and typological examination. Additional artifacts may be misidentified or ambiguous in identity.

In general, technology or provenancing has determined the thrust of the investigation and thus the level of technological interpretation. Of the *c.* 365 artifacts listed, 85% were examined primarily for elemental composition, though in some of these examinations the metal structure was also investigated, for example in the study of 25 currency bars by Hedges and Salter (1979). Thus, of published analyses to date, *c.* 93 Iron Age artifacts (25%) have been investigated to attempt to answer specific questions about the technology, or examined sufficiently thoroughly to elucidate the principal aspects of technology employed. These are 33 currency bars, *c.* 23 tools and implements, *c.* 19 swords, and 18 other items including 2 possible bloom fragments, a bridle-bit, a firedog, a cauldron, a tyre, and a gang-chain.

(b) Provenancing

The first serious attempts at provenancing ore sources used in the Iron Age were undertaken by Haldane (1970) and Hedges and Salter (1979), and investigations have been pursued subsequently by Salter (1982, 1984, 1987) and Ehrenreich (1985). Elemental distribution patterns have been sought in artifacts and waste products, and compared with known ore sources.

At present, the chemical composition of smelting slag does not enable the ore source to be determined with any certainty (McDonnell 1988b, 124). The most promising impurities for potential study in Britain appear to be the trace elements in artifacts, particularly cobalt and nickel (Salter 1982).

Clear conclusions have been prevented by the heterogeneity of ores, the possibility that ores were mixed during smelting, and that slag may have been recycled (McDonnell 1988b). Other problems include

Table 2:1 Iron Age* artifacts from England and Wales which have been examined by metallography, either for metal structure or for elemental composition

Site	Artifacts	Analysis	Metallography reference
1. All Cannings Cross, Wilts	2 'Awls', agricultural blade, blade tip	E O	Ehrenrich 1985, 121-2, 207, ACC1b-ACC3a
2. Baldock, Herts	Firedog	M	Tylecote in Stead and Rigby 1986, 387
	Cauldron	M	Lang in Stead and Rigby 1986, 388
3. Barbury Castle, Wilts	Anvil, 2 fine tools, 3 spearheads, 5 agricultural blades, knife	E O	Ehrenreich 1985, 128-30, 207-8, BC1a-BC5b, BC6, BC7a
4. Battery Hill, Hants	Agricultural blade, knife	E O	Ehrenreich 1985, 133, 208, BTH1a-b
5. Battlesbury Camp, Wilts	Saw, agricultural blade, sword (3 frags.)	E O	Ehrenreich 1985,132-3, 208, BTC1a-b, BTC2b-BTC3b
6. Bigbury, Kent	2 Hammers, hot chisel, axe, pick, dagger, spearhead, blade, 2 shares, 10 other agricultural blades, 4 other	E O	Ehrenreich 1985, 123-8, 207, B1a-B13b
7. Beckford, Northants	6 Currency bars	M S	Hedges and Salter 1979
	Currency bar	M	Tylecote 1986, 148
8. Bourton-on-the-Water, Glos	Currency bar	M	Tylecote 1962, 210, pl. XXI, table 74
9. Buckland Rings, Hants	Blade	E O	Ehrenreich 1985, 132, 208, BR1a
10. Bury Hill, Hants	Scabbard, 3 other	E O	Ehrenreich 1985, 131, 208, BH1a-BH2b
11. Cow Down, Wilts	Agricultural blade	E O	Ehrenreich 1985, 135, 208, CD1a
12. Danebury, Hants	12 Currency bars.	M S	Hedges and Salter 1979
	Cold chisel, 2 woodworking chisels, saw, 2 files (medium/coarse-cut), 2 adzes, 2 agricultural blades, pick, 3 blade fragments (?knife), 3 other.	E O S	Salter 1984, 435, Mf13:C4 table 122

Table 2:1 [cont.]

Site	Artifacts	Analysis	Metallography reference
Danebury (contd.)	?Bloom, ?scriber, 3 woodworking chisels, saw, saw/spear, 3 spearheads, 12 agricultural blades, share, 7 blade frags. (?knife), currency bar, 26 other.	E O	Ehrenreich 1985, 135-146, 149, 208-9, D1a-D5b, D7a-D33b, D122
13. Dinorben, Clywd	?Bloom	E M	Davies in Gardner and Savory 1964, 226-7, no. 1859
14. Fifield Bavant, Wilts	Agricultural blade, knife	E O	Ehrenreich 1985, 163, 211, FBD1a-b
15. Gretton, Northants	Currency bar	E M	Riley 1973
	7 Currency bars	M S	Hedges and Salter 1979
16. Grimthorpe, N. Humberside	Sword	M	Lang 1987, 71, no. 10
17. Gussage All Saints, Dorset	File (fine-cut), cold set, 4 punches, knife, bridle-bit, rivet, 3 bars (?smithing waste), 6 unidentifiable fragments.	M	Tylecote 1975; Tylecote in Spratling et. al. 1980, 284-291
	File (fine-cut)	M	Fell 1985
18. Hunsbury, Northants	6 Metalworking chisels, 2 hammers, 1 file (medium-cut), 6 hearth tools, hooked block, woodworking chisel, 6 adzes, axe, saw, pick, 3 daggers, 7 spearheads, 10 agricultural blades, 8 shares, 10 blades (?knife), 3 other implements, 10 currency bars, tyre, linch-pin, 25 other	E O	Ehrenreich 1985, 163-186, 211-4, HNY1b, HNY4a-b, HNY5b-HNY6b, HNY7b-HNY11b, HNY13a, HNY14a-HNY18b, HNY19b-HNY20a, 21a-b, HNY23a-HNY25b, HNY27a, HNY28a, HNY29b, HNY31a-HNY33b, HNY35a, HNY36a-HNY38a, HNY39a-HNY40b, HNY41b-HNY44b, HNY46b-HNY47a, HNY48a-HNY58a, HNY59a, HNY60a-HNY63a, HNY64b-HNY68a, HNY69a-HNY70b
19. Isleham, Cambs	Sword	E M	Lang in Stead et. al. 1980, 71-2; Lang 1987, 71, no. 12
20. Little Somborne, Hants	Spear, ?share tip	E O	Ehrenreich 1985, 186, 214, LSa-b
21. Little Waltham, Essex	2 Iron lumps (?bloom fragments)	M	Tylecote in Drury 1978, 115, pl. XI
	5 Other	E O	Ehrenreich 1985, 186-8, 214, LW2a-b, LW4a-b, LW6b

Table 2:1 [cont.]

Site	Artifacts	Analysis	Metallography reference
22. Llyn Cerrig Bach, Gywnedd	Gang-chain	E M	Richardson & Richardson in Fox 1946, 84
	Tyre	E M	Cook in Fox 1946, 75-6
	4 Swords	M	McGrath 1968
23. Llyn Fawr, Glamorgan	Sickle	O	Northover in Savory 1980, 235
24. Meon Hill, Hants	5 Currency bars	E O	Ehrenreich 1985, 189, 214, MH1a-MH3a
25. Nadbury, Warks	Currency bar	E O	Ehrenreich 1985, 190, 214, MH3NDB
26. Old Down Farm, Hants	2 Points (?pins), ?knife blade 4 agricultural blades, 3 currency bars,	E O	Ehrenreich 1985, 190-4, 214, ODF1b, ODF2b, ODF4b, ODF5a, ODF6a, ODF7a, ODF11a-b, ODF12b
27. Orton Meadows, Cambs	2 Swords	M	Lang 1987, 70-1, nos 2 and 11
28. Sadberge, Co. Durham	Sword	E M	Lang 1987, 72, no. 15
29. Stanwick, N. Yorks	2 Swords	E M	Lang 1987, 72, nos 16 and 17
30. Waltham Abbey, Essex	Sword	E M	Lang & Williams 1975, 202-3, figs 3 & 4; Lang 1987, 71, no. 13
31. Walthamstow, Essex	Sword	M	Lang 1987, 71, no. 4
32. Whitcombe, Dorset	Sword	M	Lang 1987, 72, no. 14
33. Wilsford Down, Wilts	Agricultural blade	E O	Ehrenreich 1985, 131, 208, BC7WD
34. Winklebury, Hants	Knife, currency bar	M	Tylecote in Smith 1977, 82; Tylecote 1986, 152, fig. 93a
35. Winnal Down, Hants	Lump	M	Tylecote in Fasham 1985, 93
	Spike, 2 nails	E O	Ehrenreich 1985, 200-5, 215-6, WND1a, WND4b, WND14a

Table 2:1 [cont.]

Site	Artifacts	Analysis	Metallography reference
36. Worthy Down, Hants	Currency bar	M	Myers 1922, 133T-134T
	Cold set, fine tool, bar tip scriber, 18 currency bars, linch-pin, blade tip (?knife), 3 other	E O	Ehrenreich 1985, 195-200, 215, WD1a-WD7b, WD8b-WD10b, WD11a-b, WD12a-b, WD13a, WD13b
Unprovenanced			
37. R. Thames	Sword	E M	Lang 1987, 70-1, no. 3
38. Dorset Museum	Currency bar	M	Brewer 1976, 1-2, figs 1-3
39. ?	2 Currency bars	E M	Gowland in Smith 1905, 194
Uncertain date			
40. Reading Museum	Sword	M	Tylecote and Gilmour 1986, 150, no. 32, fig. 64
41. R. Thames, Kempsford, Glos	Spearhead	M	Tylecote and Gilmour 1986, 115-7, no. 38, fig. 48
42. R. Thames, Little Wittenham, Oxon	2 Swords	M	Tylecote and Gilmour 1986, 160-4, nos 27 and 29, figs 65-6

'Other' includes structural fittings, domestic items, unidentified items etc.

* Dating and context is usually given in metallurgy report, or in the site report in which the contribution is to be found. For Hunsbury see also Knight 1984, for Llyn Cerrig Bach see also Savory 1976)

E Elemental composition
M Microstructure
O Macrostructure
S Slag/inclusion composition

the contribution of impurities from fuel and furnace linings, and elemental partitioning between metal and slag during smelting. In artifacts, the problems also include segregation effects during smithing, especially at weld lines, and the presence of any fluxes employed. In addition to all these difficulties, many Iron Age ore sources may have been worked out, enabling few, if any, valid comparisons.

(c) Analysis of technological by-products

Slags have been analysed in order to characterise the by-products from smelting, smithing, and other technological processes, and to identify the nature and efficiency of these processes. Iron smelting and smithing slags are notoriously difficult to distinguish from each other. Smelting slag is more easily distinguished if it has a 'ropey' appearance characteristic of tapping, or has a significant manganese content (McDonnell 1986c). Other morphological attributes are less diagnostic (McDonnell 1986a; 1988b; Crew 1988b), and in general, a combination of morphology, and chemical and mineral composition needs to be considered (McDonnell 1986a).

Iron Age slags have been analysed by Morton and Wingrove (1969), Clough (1985; 1986; 1987), McDonnell (1986a) and others, in attempts to identify the types of smelting furnaces and the efficiency of the process. Other slags from Iron Age contexts have been analysed in order to determine the technological process, and to characterise these residues more fully (e.g. Clough 1986; McDonnell 1986a; 1986b; 1987a; 1987b; 1988; 1989; Salter 1984; 1987).

Non-metallurgical vitrified products have also been investigated (e.g. Evans and Tylecote 1967; Biek 1970).

(d) Dating

The dating of iron artifacts by radiocarbon measurement has been investigated by Van der Merwe (1969). The major problem is that traditional extraction and counting methods for ^{14}C require substantial volumes of metal. The method has thus been more appropriately applied to the dating of charcoal entrapped in slags. Accelerator mass spectrometer counting for $^{14}C/^{13}C$ ratios now offers the opportunity for dating small volumes of metal.

In situ hearths and furnaces have been successfully dated by archaeomagnetic determination of thermo-remanent magnetism in the iron which was originally present in the clay of the structure.

2.3.5. Experimental reconstructions

Relevant experimental studies include iron smelting and smithing, coin production, and the replication of artifacts and tool marks.

Reconstructions of bloomery smelts have attempted to quantify yields and efficiency of early furnaces by varying materials used and operational parameters (e.g. Wynne and Tylecote 1958; Tylecote *et al.* 1971; Clough 1986; Crew and Salter 1989). Blooms produced from some experimental smelts have been subjected to chemical and structural analysis, and in some cases have also been forged in order to quantify time and raw materials (e.g. Crew 1988b; Crew and Salter 1989).

Surface carburization was investigated in early experiments (Shaw Scott 1907; Stead 1918), and the data is still used today (e.g. Tylecote 1986, fig. 89, table 73). Investigations into segregation effects of impurities during smithing have given useful insight into the problems of interpreting metallographic sections (e.g. Pleiner 1973; Tylecote and Thomsen 1973). Another relevant metallurgical investigation was the copying of a bronze-coated bridle-bit link from Gussage All Saints (Spratling *et al.* 1980, 290-1).

Coin production has been investigated in terms of the possible connection of 'coin pellet moulds' (Tylecote 1962; 1986), and methods of striking (Sellwood 1976; 1980) and casting coins (Van Arsdell 1986).

Decorating techniques have been examined by three workers in particular (all metalworkers in their own right). Maryon was the first to attempt to characterise chasing tools, though principally ones of Bronze Age date (Maryon 1938a; also Maryon 1938b; 1944; 1949; 1971). The terminology of tools and tool marks applicable to Iron Age decorating techniques was refined by Lowery and Savage, who also developed a replication method for studying tool marks with the light microscope (Lowery *et al* 1971; see also Lowery and Savage 1976; Lowery *et al.* 1976; 1982; 1983).

Replications of artifacts or tool marks to investigate methods of manufacture include the copying of a torc from Ipswich, Suffolk (Brailsford and Stapley 1972, 228-234), methods of early wire production (Carroll 1972; Oddy 1977; 1979; 1980b; 1987), and analysis of tool marks on a shield from the Witham, Lincolnshire (Shorer 1971) and on a sword from Isleham, Cambridgeshire (Stead *et al.* 1980).

2.4. Survival and recognition of Iron Age ferrous tools

The survival, discovery and recognition of archaeological ironwork is highly selective (Saunders 1977; Alexander 1981; Manning 1981).

The life cycle of an iron tool is summarised in Figure 2:1; the manufacturing stage of the cycle is shown also in Figure 1:6. The functional stage includes repair and reforming. Many tools may be 'extracted' from the cycle at this stage, including tools lost, discarded, or deposited (e.g. in burials, hoards, and ritual deposits), and may also include tools recycled into other types of artifacts. Survival, discovery, recognition, and recording form the archaeological data.

Factors which may affect recognition and identification of iron tools are principally condition, modification, and changes in use.

(1) Corrosion

Corrosion effects seldom enable full characterisation of ferrous tools; attributes such working edges infrequently survive yet these may be the only diagnostic features, particularly on small tools with fine working edges.

There are two notable situations which may enable the survival of iron in relatively pristine condition. Firstly, continuous waterlogging (i.e. anaerobic conditions) in non-aggressive environments sometimes results in only superficial corrosion (Biek 1963; 1979). Secondly, burning at temperatures above 200°C may form a layer of bright red haematite ('fire patina'), and this can be protective in burial (Cronyn 1990, 180). These conditions may occur in hearths, destructions, cremations (e.g. de Navarro 1955, 232), and possibly ritual and other contexts.

(2) Completeness

Incomplete tools often are not identifiable if the working edge has not survived or if the means of holding or striking the tool cannot be ascertained. Very fragmentary tools may not be recognisable at all.

(3) Alteration

Broken or worn-out tools may have been repaired, reformed, or recycled, particularly those of acknowledged quality. Archaeological examples of modified tools have seldom been recognised, though at Danebury a saw-blade was reformed into a spearhead (Sellwood 1984, 361, fig. 7.19, 2.102), and another saw-blade was repaired (Sellwood 1984, 351, fig. 7.11, 2.42).

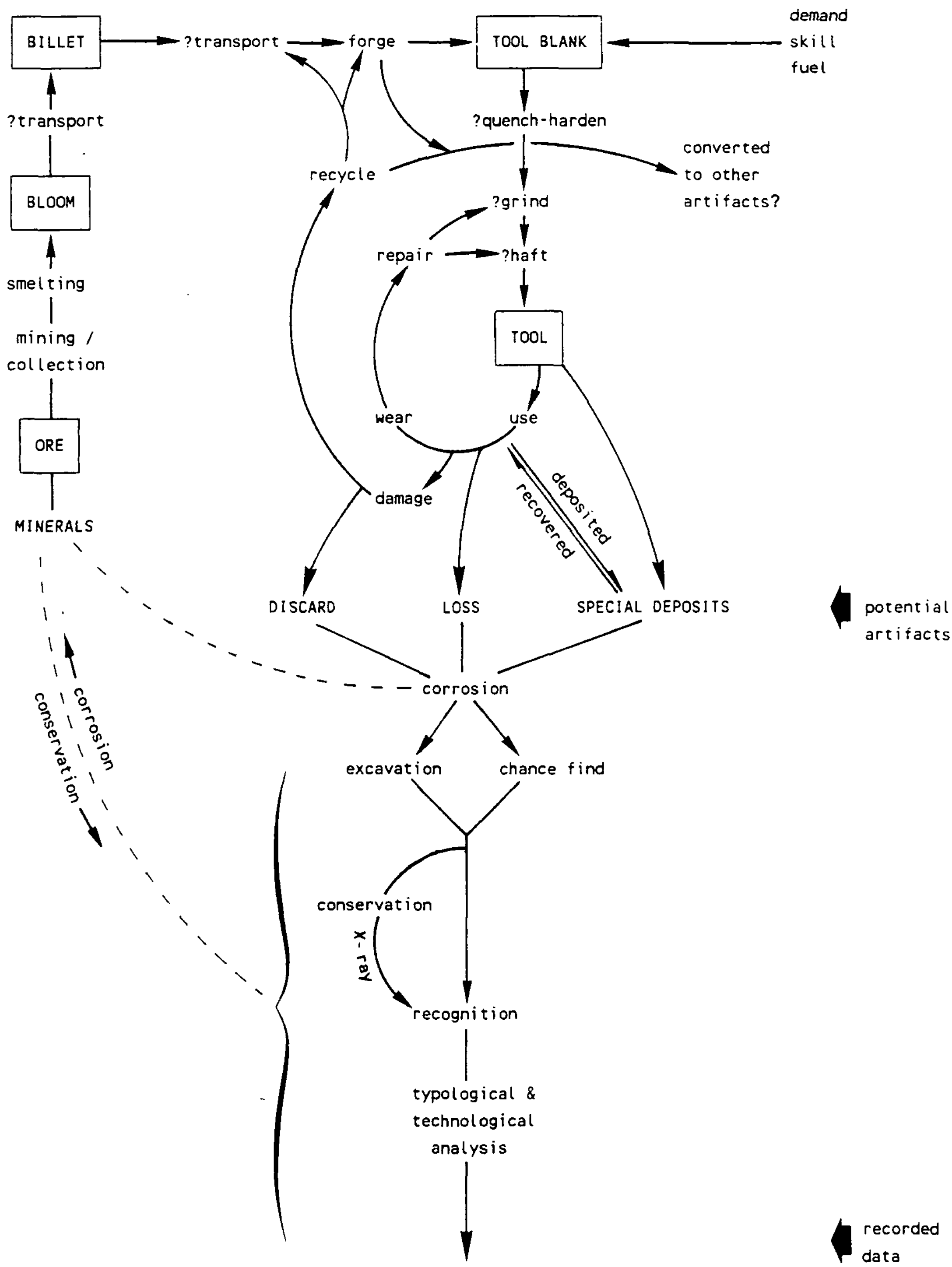


Figure 2:1 Life cycle of an iron tool

(After Saunders 1977, fig. 2; McDonnell 1988b, fig. 2)

(4) Multi-purpose tools

Some tools may have served several functions, either within a single craft, or for more than one craft. Although some multi-purpose tools may have had similar functions, others may have been employed for very different purposes (e.g. scribers and wax-modelling implements).

(5) Method of use

Method of use of tools may alter, for example techniques which once employed struck tools may later develop into methods employing hand-propelled tools, or vice versa. Additionally, individual workers may have had preferred methods of using tools.

(6) Analogy

Determination of tools, like other categories of artifacts, relies on inferences and analogies - aspects which are discussed earlier in this chapter. Commonly, identifications are uncertain, either in terms of the craft for which they were intended, or (and) the precise purpose. It seems very likely that many Iron Age tools would have been devised for special needs; even if such tools are found in archaeological contexts with unambiguous craft associations, their identity may still go unrecognised.

2.5. Analytical procedure of the present study

2.5.1. The tool sample

I. Typological sample

Archaeological publications were searched for Iron Age metalworking tools and possible tools; museums housing the artifacts were visited in order to study the tools and any other related material. The catalogue is intended to include the principal types of tools rather than to be a definitive list of all surviving possible metalworking tools. Due to time constraints, therefore, a number of less readily obtainable local periodicals were not consulted, nor were museum collections examined unless known to include relevant material. Tools from excavations awaiting post-excavation analysis and publication were examined if phasing had been undertaken, and if the finds were made available for study prior to publication.

Many assemblages of ironwork, particularly those from excavations or discoveries made last century or earlier this century, have never been X-rayed. During the course of this study, selected groups of possible tools from such assemblages were X-rayed if loan was permitted, and this enabled the identification of more tools than had been previously recognised. Some known tools were X-rayed in order to examine structural features. Surface detail of a number of tools and possible tools was clarified using standard conservation techniques (Section 2.5.2).

The catalogue of ferrous metalworking tools determined forms Appendix A. Other tools are evaluated in Chapter 3 in terms of a possible role in metalworking, but if on balance the type cannot be ascribed a fairly certain or possible metalworking function the examples are not included in the catalogue. Some metalworking tools which are available for study cannot be assigned an Iron Age date with any certainty: a number are from discoveries or from uncontrolled excavations, others are from contexts with unclear stratigraphic relationships or archaeological associations, including some tools which may be residual in context. Tools which are insecurely dated have only been incorporated if on form or associations an Iron Age date seems likely, or if inclusion contributes to the study, providing that on balance the evidence does not indicate a post-Iron Age date.

The catalogue comprises 231 tools from 52 sites and hoards. The geographic distribution of these sites and hoards is shown in Figure 2:2, and Appendix C provides further information, serving also as a concordance for the tool sample.

II. Metallographic sample

The metallographic examinations involve 62 samples from 48 certain or probable metalworking tools. In addition, a further 7 artifacts which are not metalworking tools are investigated to enable comparison of certain types of tools (see below). The sample population derives from two sources, indicated also in Figure 2:3 for clarification.

(1) 42 samples taken by the writer, from 30 metalworking tools and 4 other tools: 13 of the samples from metalworking tools are second or third sample from individual tools (mainly from eyes and second faces of hammers). The 4 tools of non-metalworking function are 3 coarse-cut files, to enable comparison with other files (Chapter 3.8), and an engraved 'saw' (Plate Ia), included for the interpretation of the tool marks. Six of the 42 samples are flakes of corrosion products which have yielded information on residual metal structure, but one (S46) gave inconclusive results and is therefore excluded from discussion in Chapters 3 and 4.

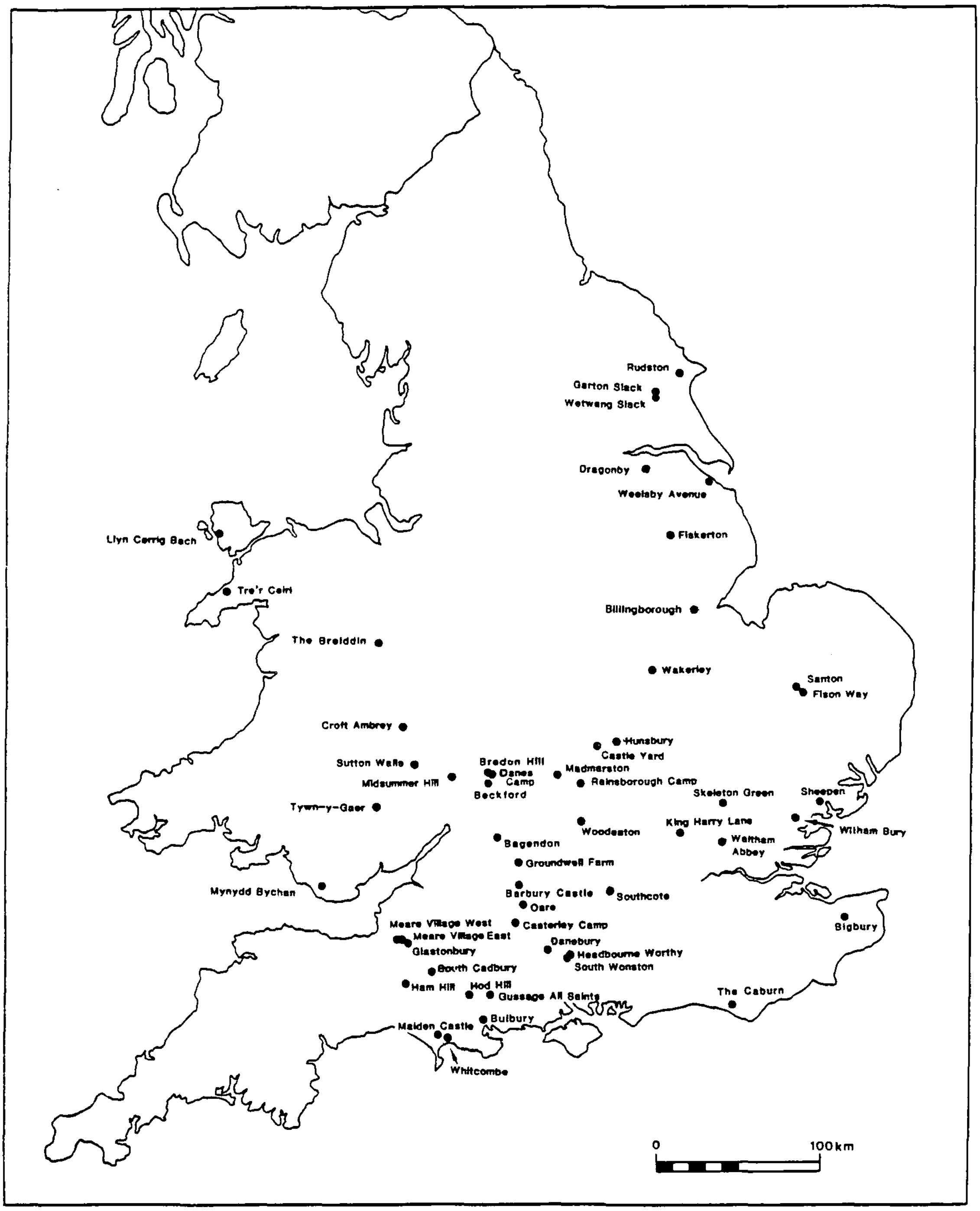
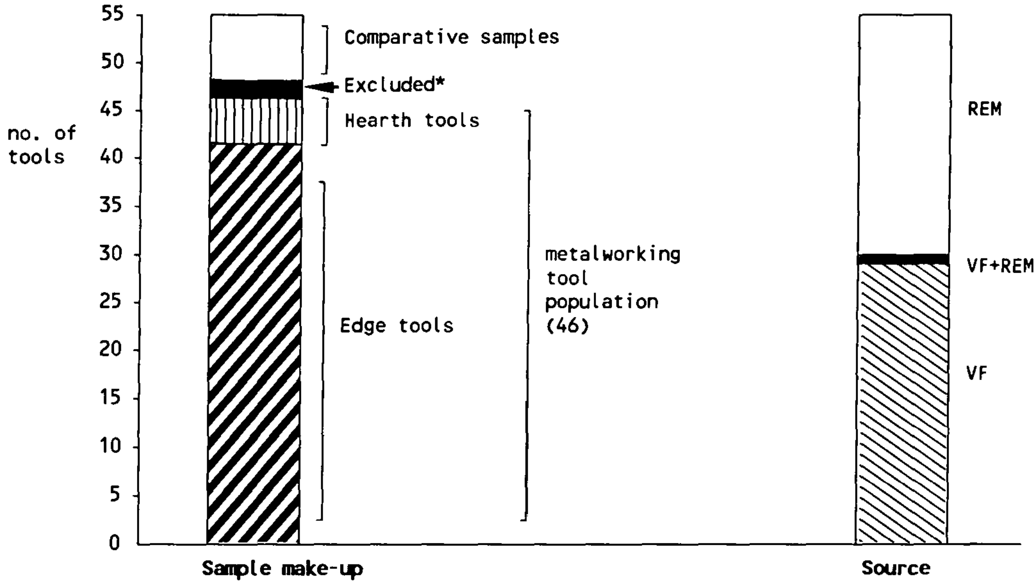


Figure 2:2 Map showing the distribution of sites with metalworking tools



* Inconclusive results

VF Samples taken by the writer

REM Samples derived from Ehrenreich collection (for elemental analysis: Ehrenreich 1985)

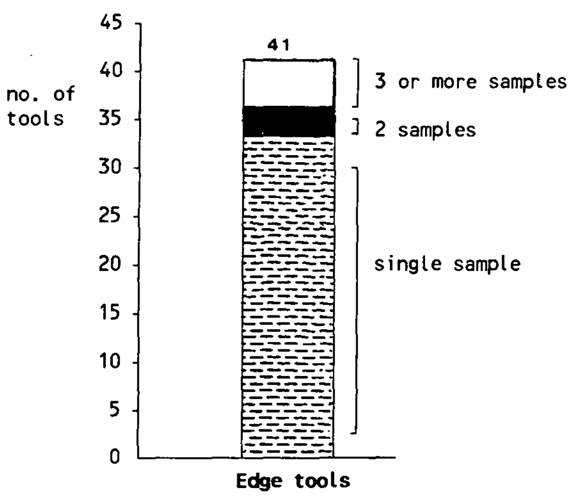


Figure 2:3 The tool population sampled for metallography

(2) Ehrenreich (1985; 1986) had previously sampled 26 metalworking tools and possible tools (27 samples), but his research was for elemental composition rather than metal structure and technology. These samples have been made available to other workers, and the present study has benefited substantially from the loan of these samples for re-examination. The 27 samples (mainly pokers and chisels) are also included in this study; three derive from artifacts which are probably not metalworking tools, but they are included to enable comparison of tools in Chapter 3.4 and 3.10.

A large proportion of Ehrenreich's other samples were screened in order to assess the general level of technology applied to artifacts other than metalworking tools in the assemblages.

Thus, the metalworking tool population usefully sampled for metallography is 41 edge tools and 6 hearth implements (Figure 2:3). Of the 231 metalworking tools catalogued in Appendix A, 20% have therefore been examined by metallography.

Owing to the complexity of the examination procedure and the information determined by metallography, these results are catalogued separately from the typological data in Appendix A. The results of the individual examinations are catalogued in Appendix B (cross-referenced in Appendices A and C), and the seven tools of less certain function are incorporated at the end of the sequence.

2.5.2. Visual and X-radiographic examination

Metalworking tools and possible metalworking tools were examined alongside their X-radiographs, if available. Single tools were not normally studied if a special visit would have been required, due to time restrictions. A few assemblages had suffered considerable deterioration since publication; if X-radiographs were not available, little further information could be retrieved. In these cases, it was considered more appropriate to use the published descriptions. In addition, a few artifacts were unavailable for study owing to loss.

The following catalogued tools were not visually examined by the writer: Nos 15, 22, 28, 42, 69, 70, 74, 75, 85, 87, 92, 110, 115, 117, 118, 127, 136, 137, 140, 149, 160, 162, 163, 165, 173, 176, 177, 181, 183, 184, 203, 222, 223, 224, 225, and 226.

During the course of this study, individual metalworking tools, selected groups of tools, and possible tools, were X-rayed from the following sites: (All Cannings Cross), Bigbury, Bredon Hill, The Breiddin, Bulbury, Casterley, Headbourne Worthy, Hunsbury, Llyn Cerrig Bach, Mynydd Bychan, Oare, Sheepen, Southcote, South Wonston, and Twyn-y-Gaer.

Groups from the following sites were X-rayed and accretions were selectively removed from areas of interest: Barbury Castle, Budbury, Fiskerton, Glastonbury, Gussage All Saints, Ham Hill, Meare Village East, Meare Village West, Rudston, (Swallowcliffe Down), Weelsby Avenue, Wetwang Slack, and Whitcombe.

X-ray exposures were taken with a bench unit (Hewlett-Packard Faxitron) at low cathode current (3mA) and tube voltage up to 110KV. Artifacts were normally X-rayed at two angles, and at several different voltages; low exposures to reveal outline, higher exposures to reveal internal detail. Film of either standard attenuation (Kodak CX or Agfa D7) or slow speed (Kodak MX or Agfa D4) was used within cassettes containing lead screens (e.g. 0.02mm at the front, 0.125mm at the back) in order to achieve the best possible results.

Where accretions were removed, these were from above the 'original surface' so as to reveal detail of working edges and other significant features such as cross-section. Mechanical methods were used, usually air abrasion at low pressure (e.g. 40psi $\equiv$ 280kN/m^2) using 53μm aluminium oxide, under a binocular microscope at X10 or X20 magnification. For example, files were air abraded using a rectangular-orifice nozzle (1.5 x 0.15mm) perpendicular to the blade in order to locate the ridges by colour and density contrast within the corrosion products, thereafter a circular-orifice nozzle (0.46mm diameter) was used to clarify detail.

2.5.3. Metallographic examination procedure

Sampling

The sample position was selected with reference to X-radiographs and in regard to the local and overall condition of the tool. The integrity of working edges was respected; samples were not taken from small edges if this would be detrimental to future typological examination. For example, hammers with small faces were sampled transversely a few millimetres from the face. It was thought that sampling at this point should offer almost the same information on heat-treatment, though the hardness may be marginally less than at the extant face. Where hammer faces were well-worn, it is possible that equal or more representative evidence of the original structure was gained by sampling the side of the hammer. Some tools were sampled specifically for study of residual metal structure, either because the tool was severely corroded at the area of interest, or because of difficulties in sampling for metal. Metal samples were obtained using whichever of the following methods was most appropriate to the condition of the tool.

(a) Jeweller's piercing saw, fitted with a fine blade (thickness *c.* 0.2mm), using alcohol as coolant. This method was found to be suitable for robust objects with relatively soft metal cores.

(b) Diamond-edged dental cut-off wheel (diameter 20mm, thickness 0.2mm) fitted to a speed-controlled pendant drill. Alcohol cooled.

(c) Low-speed sampling saw (Beuhler Isomet) fitted with a 100mm diameter diamond wafering blade of thickness 0.3mm, and lubricated with an oil-based cutting fluid. This method was used only for robust artifacts with limited corrosion.

Preparation of samples

Samples were mounted individually in low-temperature thermosetting resin of polyester type (usually Metserv 'Metset SW'). The mounted samples were ground wet using 120 grit through to 600 or 1200 grit silicon carbide papers, and polished to 1μm or 0.25μm fineness with diamond pastes and an oil-based lubricating fluid. Samples of flakes of corrosion products were similarly mounted and polished, but were examined unetched unless clusters of grains were present.

Optical microscopy

Metal samples were first examined for slag distribution and other features. The corroded layers surrounding metal sections were examined for residual structure, in particular for evidence of surface carburization. Microstructure was then developed with nital and some sections were additionally examined, after repolishing if necessary, with other reagents.

Samples were examined with an Olympus BT reflected light microscope, normally at X50 to X500 magnifications, and at X1000 if appropriate. A Vickers M55 Projection Microscope was used for the photography of some of the sections at low magnifications.

Etchants and stains

The following standard etchants and stains (Samuels 1980) were used:

(a) Nital: 1% or 2% (v/v) nitric acid (1.4 SG) in Industrial Methylated Spirits (95%), or at greater dilutions if sections etched rapidly.

(b) Picral: 4% (w/v) picric acid in Industrial Methylated Spirits (95%), sometimes mixed 1:1 with 1% nital.

(c) Hot alkaline sodium picrate: 2g picric acid + 25g sodium hydroxide in 75ml water, and boiled for 3 to 10 minutes.

(d) Potassium metabisulphite: 10% (w/v) aqueous solution.

Hardness measurements

Hardness measurements indicate the overall value for an area of a section, and can be used as an aid to identification of individual microstructures. The hardness values used in this study are Vickers Pyramidal Hardness Numbers determined with a square-based pyramid of 136° apex angle, under the stated load. For example, 123 HV 0.2 is a hardness of 123 obtained using a 0.2kg load. Vickers Hardness Number (HV) is defined as the quotient of the load in kg force over the pyramidal area of the impression in mm^2 (B.S. 427:1961).

For consistency, hardness was normally measured on a Shimadzu low-load tester (Ancient Monuments Laboratory), usually with a 200g load for 30s duration, unless a higher load was necessary (e.g. 500g for particularly hard martensite). The microhardness values stated were averaged from three readings if sufficiently close in value, or from a larger number of readings if a broader range was obtained. Macro-hardness values were measured on a Vickers instrument.

Within the microhardness range 5-100g, the values obtained are greater than those obtained using higher loads, and may be as much as 50% higher (Tylecote 1986, 7). This is due to the polished surface layer of the metal being harder than the substrate grains. An applied load above 100g is said to have little effect on the result (Tylecote 1986, 7, fig. 2), although results from this study and those of other workers (G. McDonnell pers. comm.) suggest that marginally higher values are normal.

Macro readings (1kg or 5kg) were only taken where lighter loads proved inadequate, for example where two or more constituents were present in a small-grained structure.

Grain size measurements

Grain size may reflect chemical heterogeneity, thermal treatments, and cooling rate. Grain size, the number of grains per unit area, is graded from 1 to 8, equivalent to 1 - 128 average grains per $inch^2$ at x100, or 16 - 2048 average grains per mm^2 (B.S. 4490:1969, table 1).

The ASTM grain size numbers were estimated with an eyepiece graticule at X100 magnification. Estimations could not be made where grain boundaries were not visible, for example on some martensitic sections.

Scanning electron microscopy

Where the presence of phosphorus was suspected from the structure, or where light-etching lines were present, qualitative or semi-quantitative elemental determinations were made in order to investigate compositional variation and to assist interpretation of the microstructure.

Scanning electron microscopy coupled with energy-dispersive X-ray analytical facility (SEM-EDXA, detection limit 0.1%) was used. Prior to examination, the sections were lightly etched in nital and carbon coated. Analytical facilities were not always available throughout the course of this study and thus determination was limited to only a small proportion of the samples. Quantitative facilities were not available.

Some sections revealed constituents which could not be resolved by optical microscopy. A selection of these samples were examined by SEM, usually in secondary electron imaging mode.

The SEM examinations were undertaken on the writer's behalf, by Paul Wilthew and Gerry McDonnell, Ancient Monuments Laboratory, London, and by Ian Brough, Department of Metallurgy, University of Manchester.

CHAPTER 3

THE TOOLS

3.1. Introduction

The tools are divided into nine main groups based principally on form and usage, and further divided where appropriate. The criteria for inclusion of the tools in the catalogue (Appendix A) are discussed in Chapter 2.5.1. A number of other iron tools are evaluated in Chapter 3 in terms of a possible role in metalworking, but if on balance the type cannot be ascribed a fairly certain or possible metalworking function the examples are not incorporated in the catalogue.

Each category of tool is discussed, where relevant, in terms of attribution, typology, technology, likely purpose and method of use. Probable dating is summarised at the end of each Section, though the basis for dating is given in Appendix A or Chapter 5. Metalworking, and other associations or contexts, are given if potentially relevant to interpretation of the tools in functional or social use, though these aspects are discussed more fully in Chapter 5. In order to demonstrate earlier occurrences of tools, variations in tools, or possible functions, examples are cited from outside the geographic and chronological limits of the study, and for the latter reason also from historical and modern usage where necessary. Metalworking tools in materials other than iron are also discussed.

Some of the tools fall into more than one of the main groups and are therefore referred to under two or more Sections. The small tools with fine working edges present special problems in attribution, discussed in Section 3.10.1. These tools are therefore incorporated into one main group but sub-divided by form and likely function. Section 3.11 comprises five categories of tools which have not been recognised from the area of study, but tool marks on metalwork from Britain suggest their employment, or possible examples of the tools are known from the Iron Age on the Continent.

Individual tools are identified by a sequential catalogue number (Appendix A) which gives access to their context, date, description, and publication and analytical references. Each Section in Chapter 3 is preceded by a list of the catalogue entries (Nos 1 - 231) of the tools discussed, the figure numbers (A1 - A24) in which these are illustrated, and the sample numbers (S1 - S69) of the tools which have been examined by metallography (Appendix B). These are followed by a list of the tools with an indication of the security of their chronological attribution, according to the following scheme:

A. Tools from definite Iron Age contexts

B. Tools from probable Iron Age contexts

C. Tools not from definite Iron Age contexts, but from form or associations, probably Iron Age in date

D. Tools from mid-first century AD horizon; type not known from earlier contexts, but potentially an Iron Age type

E. Tools from mid-first century AD or later horizon, or unstratified; type not distinctive of period, possibly post-Iron Age in date.

The main groups in the catalogue sequence are as follows: hearth implements/pokers (Section 3.2, Nos 1 - 32), tongs (Section 3.3, Nos 33 - 44), anvils and stakes (Section 3.4, Nos 45 - 54), swages and 'moulds' (Section 3.5, Nos 49, 50, 55, 58), hammers (Section 3.6, Nos 56 - 89), sets and chisels (Section 3.7, Nos 90 - 117), files (Section 3.8, Nos 118 - 161), hot punches (Section 3.9, Nos 162 - 168), and tools for fine working (Section 3.10, Nos 169 - 231).

3.2. __Hearth implements (pokers)__

Nos 1 - 32. Figs A1 - A3. Metallography S1 - S6.
Date category *A*: Nos 1, 5, 8, 20, 23, 24, 27, 28, 31.
B: Nos 18, 22, 26. *C*: Nos 2, 3, 4, 6, 7, 10 - 14, 16, 17, 19, 21, 25.
D: Nos 9, 29, 30. *E*: Nos 15, 32.

During the Iron Age, metalworking hearths were fuelled normally with charcoal, and supplied with air from bellows in order to sustain the fire at the required size and temperature (Tylecote 1986, 223-5). The fire was managed with hearth implements to maintain the correct fuel supply, and to remove accumulations of slag and other debris (CoSIRA 1955, 17-18; Manning 1985, 12).

There are two types of hearth implements known from the Iron Age (Figure 3:1), both generally termed 'pokers', the simple tapered rod and the spatulate-ended 'poker'. The former was presumably used to

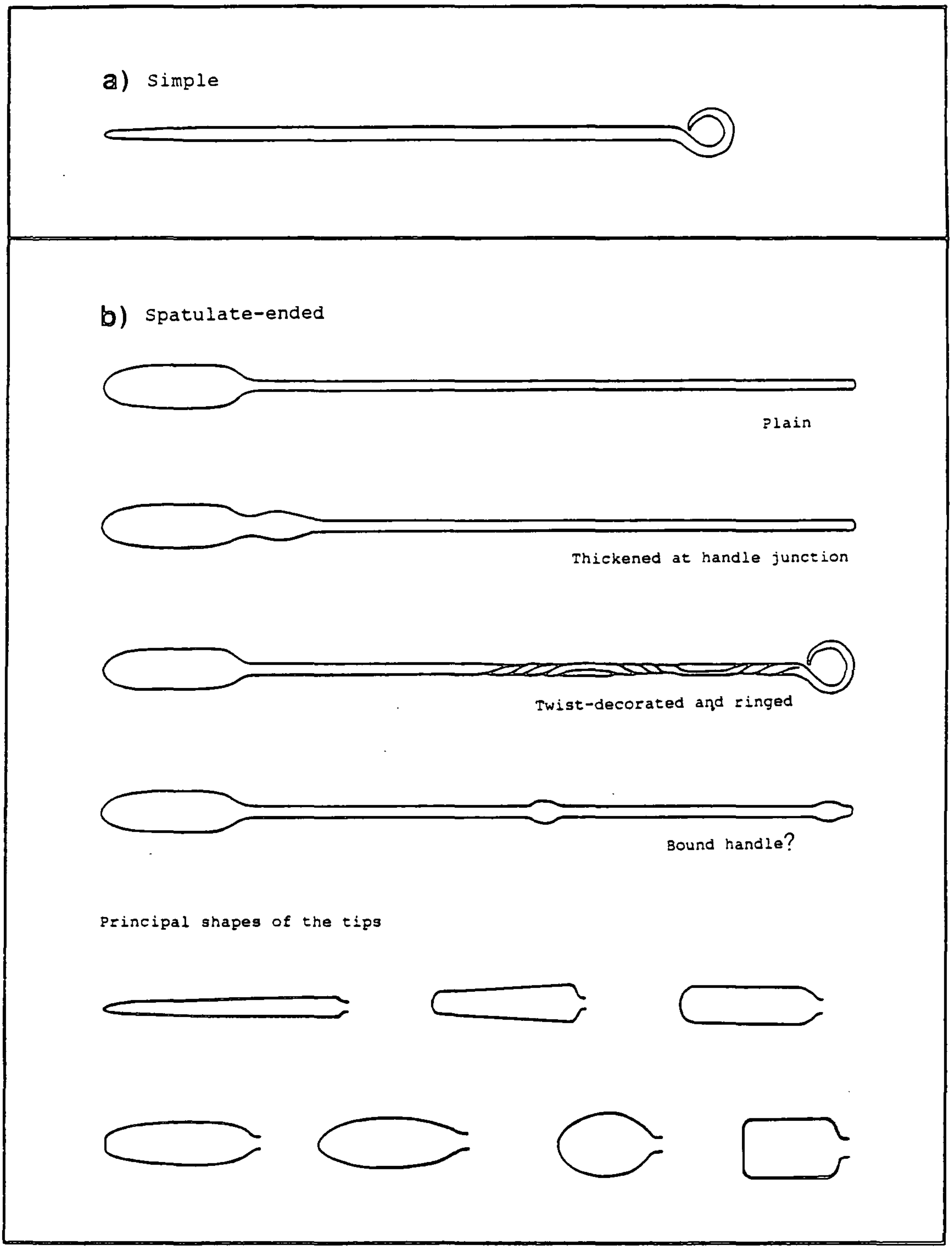


Figure 3:1 Diagrams of principal types Iron Age pokers

rake fuel residue, whereas the latter may have served also to heap or spread the fuel.

Spatulate-ended 'pokers'

The spatulate-ended poker, which is sometimes called a 'slice' (Saunders 1977, 16), is the more common form of hearth implement known. Déchelette termed these *'tisonniers'* or hearth shovels (Déchelette 1914, 1427, fig. 639). Incomplete examples have sometimes been considered to be primitive forms of agricultural shares (Fell 1936, 67, no. 25; Manning 1964, 60), a view which is sustained by some writers (e.g. Rees 1979, 57-8, fig. 66).

The principal types and the range of the forms of the tips are shown in Figure 1:3b. The more frequent, parallel sided or tapered wedge-shaped blade is seen in Nos 2, 3, 5, 6, 7, 12, 13 and 14. Other blade forms range from rectangular (Nos 15 and 28), extended narrow (Nos 1, 10, 11), oval (Nos 9, 16, 17, 26 and possibly No. 8), sub-circular (Nos 18, 19, 20) to circular (Nos 21 and 22), with variations in between. A flat tip is a feature of some blades whereas others are curved at the front; both forms are represented in the better preserved examples, which seem to have been made intentionally in either form. A selection from Hunsbury are shown in Plate Ib to indicate the variants from a single site.

Rodwell (1976) discusses the three implements from Witham Bury (Nos 2, 3, 4), and proposes the following classification on the basis of the form of the shaft:

Type A. Square-sectioned shaft decorated by twisting, and terminating in a knob or ring

Type B. Square- or round-sectioned plain shaft, often terminating in a knob, ring, or thickened hand grip

Type C. Round-sectioned shaft, plain and without a knob or ring, possibly insulated with an organic binding.

Rodwell's Type C is represented by No. 2 and possibly No. 28. Rodwell suggests that a binding of organic material may have been present on the terminal portion of the shaft of No. 2, secured by the swelling at mid-shaft, and at the tip (Rodwell 1976, 45).

One attribute of the Witham examples which Rodwell (1976) does not comment upon is the lateral swelling of the shafts just behind the blade-handle junction. This is most noticeable on the Witham pokers, but is also present on No. 7, and possibly in a reduced form on Nos 8, 16, 17, 19, 20 and 25, though accretions make this difficult to determine. The swelling may be a feature arising from welding the blade to the handle, or may have been created for visual balance (as presumably were twisted shafts), or for another reason.

The 'dished poker' from Waltham Abbey (No. 9) has a tang, and was probably hafted with a wooden handle (Manning 1985, 12). Poker No. 11 appears to have a tang set close to the blade, but is severely corroded and the pointed 'tang' may be merely a result of corrosion and cleaning. Other pokers, in particular Nos 16 and 24, may appear to be tanged, but are angled by corrosion damage.

The classification proposed by Rodwell (1976) seems perhaps too narrow to encompass all the variants which are now known. Any division should probably also take into account the form of the tip, thickening of blade-handle junction, as well as the form of handle. At present, however, only eight of the twenty-eight known spatulate-ended 'pokers' are sufficiently complete to attempt any division, which is a low sample size to usefully classify. There are no apparent geographic trends to account for the variants.

Simple pokers

Poker No. 29 is the only known complete example of the simple form of poker. Difficulty in identifying fragmentary examples may account for the low number known.

Three fragments of possible pokers are Nos 30, 31 and 32. The latter may conceivably be part of a spatulate form of poker, whereas the other two are more probably fragments of simple pokers. No. 31 has an off-set 'handle' with small ring.

Decoration

Two pokers (Nos 1 and 10) are decorated with twisted handles. Decoration appears to be a more common feature of pokers from the Continent, for example from Manching, Bavaria (Jacobi 1974, 101-3, Taf. 30 nos 533, 537, 541-2), Stradonice, Bohemia (Pič 1906, pl. XXXVI nos 10, 11, 17), and Mont Beuvray, Gaul (Bulliot 1899, 29, pl. VI).

Terminal rings

Pokers Nos 1, 5, 6, 7, 29 and 32 are ringed; Nos 4 and 8 have swellings with possible perforations at the ends of the handles and thus may also have been ringed. The lengths of the pokers with rings, if these were suspension loops, may give an indication of the height of the hearths used in the Iron Age. Although tools need not have been suspended from the hearth structure, as is common practice today, pokers nevertheless would have been close at hand. The complete pokers with rings suggest hearths at waist-height.

Other possible pokers (not catalogued)

(1) Meare Village East: now lost, but listed in Gray's catalogue as 'spatulate end of a poker, similar to I61 and I129 from the W. Village', i.e. like Nos 18 and 24. (Coles 1987, 127, no. I93.)

(2) Thetford, Norfolk: oval tip and part of the handle of a possible Iron Age poker from the defences of Thetford Castle. Associated with Iron Age, medieval and post-medieval finds (Davies and Gregory forthcoming).

(3) Santon, Norfolk: possible fragment of a spatulate-ended poker (Smith 1909, pl. XVII, 1, top right).

(4) King Harry Lane, Herts: Burial 12, bent rod in two pieces - a very doubtful poker (Stead and Rigby 1989, 107, fig. 160).

(5) Walesland Rath, Dyfed: a wooden 'spear-tip' with a fire-hardened tip (Wainwright 1971, 94, fig. 39, 68) suggested by Rodwell (1976, 49) to be part of a possible poker. However, the 'blade' of this artifact is larger and considerably thicker than the iron pokers and it seems unlikely that a poker would have been shaped from wood. A second 'spear-tip' (Wainwright 1971, 95, fig. 40, 69) from the same context, is similar in size and form.

Chronology

The probable dates for the archaeological contexts of the pokers may be summarised as follows:

(1) 5th century BC: No. 20

(2) ?4th century BC (hoard): No. 31

(3) ?3rd - 1st centuries BC: Nos 2, 3, 4, 23

(4) 2nd century BC: Nos 1, 5, 8

(6) 1st centuries BC/AD (hoard): Nos 9, 29, 30

(7) 1st century AD: Nos 10, 11, 15, 32

(8) later Iron Age: Nos 6, 18, 22, 24, 26, 27

(9) unstratified: Nos 7, 12, 13, 14, 16, 17, 19, 21, 25.

The surviving spatulate-ended 'pokers' thus date from the fifth century BC, and seem to continue in use into the Roman period in

Britain and on the Continent (cf. Reinach 1917, 277, fig. 280; Manning 1976, 39, no. 149, fig. 23; 1985, 12). The two which are from mid-first century AD contexts at Sheepen (Nos 11 and 15) may be residual from Iron Age metalworking activity (Rodwell 1976). Some of the Roman examples are slightly different in form, and often larger at their tips; they need not necessarily have been metalworker's implements. Short handled fire 'shovels' are also known from the Roman period (e.g. Manning in Frere 1972, 164, no. 6); a very short one, *c.* 34cm, in copper alloy, comes from the mid-first century AD Santon, Norfolk hoard (Smith 1909; Spratling 1966b).

The two decorated pokers Nos 1 and 10 are from second century BC and mid-first century AD contexts respectively. Except for No. 31, the known ringed pokers occur in second century BC and later contexts.

Metalworking associations

(1) No. 20 was found in a dump of ferrous slag in the core of the rampart at Castle Yard, Farthingstone.

(2) Pokers Nos 18, 24, and 27 from the Meare villages were found near metalworking debris.

(3) No. 23 is from a pit in an enclosure connected with metalworking at Beckford.

Other relevant associations

Pokers Nos 9, 29 and 30 are from a probable ritual deposit from Waltham Abbey, Essex. No. 31 is from a possible ritual deposit at Fiskerton, and like the preceding group was found with metalworking tools and woodworking tools.

Nos 1 and 5 were found together (with tongs No. 38) beneath a grain silo pit at Garton Slack, North Humberside. No. 6 was found (intact) in a pit at Southcote, Berkshire. No. 8 is from a hoard of ironwork found at the tail of the rampart at Madmarston, Oxfordshire. No. 28 was found (broken, presumably deliberately) at the bottom of a ditch at Billingborough, Lincolnshire. Nos 2, 3 and 4 are possibly from one or more of three burials at Witham Bury, Essex, though this association is by no means certain. All these eight pokers are (essentially) complete; their deposition may have had symbolic significance, like the four above from possible ritual deposits.

Metallography

Six of the pokers from Hunsbury, which were sampled by Ehrenreich for elemental analysis (Ehrenreich 1985), were examined in this study for metal structure (S1-S6). Samples from two pokers (Nos 12 and 16) revealed high-carbon contents and were relatively slag-free, which is an unexpected use of steel of good quality. Nos 12 and 19 showed evidence of reheating, and No. 16 of possible surface decarburization - features which could be expected in hearth tools.

3.3. Tongs

Nos 33 - 44. Figs A3 - A5. Date category *A*: 38, 40. *B*: 44. *C*: 39, 43. *D*: 33 - 37. *E*: 41, 42.

Tongs were used by the iron-worker for grasping hot metal during forging (Manning 1985, 6), and by the non-ferrous metalworker for manipulating crucibles during metal preparation (Tylecote 1986, 99, fig. 52, lower). Presumably they were also used for handling hot metal during processes such as annealing, quenching, and brazing. Tongs were probably also used by the glass-worker and enameller (Bateson 1981, 87).

Simple tongs may have been devised from green withies (Coghlan 1977, 75), or from a strip of metal folded over to form simple spring tongs - like the copper alloy ones from the Late Bronze Age site at Heathery Burn, County Durham (*Inventaria Archaeologica* GB6, no. 70). On the Continent, iron spring tongs are known from the late Hallstatt period at Byciskála-Höhle in Moravia (Ohlhaver 1939, 115, Taf. 7), the Hallstatt cemetery in Austria (Ohlhaver 1939, 112), Yablonovka in the Ukraine (Pleiner 1980, fig. 11.6, 1), and also from the later Iron Age in central Europe, for example at La Tène, Switzerland (Vouga 1923, 72, no. 26, pl. XXI). However, gripping devices such as these would lack leverage and may only have been suitable for handling small workpieces and possibly crucibles. Green withies would seem inappropriate for handling hot metal or hot crucibles for any length of time, and in addition they probably lack the necessary strength for handling iron during forging.

Hinged tongs appear not to be known prior to the later Iron Age in Europe. The earliest depiction of hinged tongs are Greek of the fifth century BC (Maryon in Singer *et al*. 1954, 635).

Metalworkers today use a variety of different tongs, with the lengths of the handles (or reins) to suit preferences of the individual worker (Bealer 1969). For grasping hot metal, the jaws are either straight or curved (bowed). The latter are more adaptable to holding metals of different thickness since they provide springy tension and a tighter grip (Bealer 1969, 86).

Some of the surviving Iron Age tongs may of course have been used principally for handling crucibles, though none can be certainly ascribed this function on the basis of their context or associations. It seems likely that the iron-worker and non-ferrous metalworker may have used both large and small sizes of tongs depending on the scale of work and the process being undertaken. The tongs may be divided by length and type of jaw. Nos 33-40 are all greater than 300mm in length, Nos 41-44 are rather shorter; only No. 40 has extended jaws.

Large tongs

The five large tongs Nos 33-37 from a hoard (Waltham Abbey) are associated with other metalworking tools, which on balance are more likely to have formed a group of iron-worker's tools (Chapter 5.5a). As Manning has noted, these tongs are remarkably similar in form, which is surprising if this group formed a single tool set (cf. Manning 1985, 7). In common with other metalworking tools from this hoard, all had been deliberately bent beyond usable form before deposition.

The slender tongs, No. 40, were found with a bar with three perforations which is probably a coupler to slip over the ends of the reins to assist clamping the workpiece (cf. Bealer 1969; Ohlhaver 1939, Abb. 28, 29, 30 and 31). Couplers seem to have been more commonly devised from a ring or loop which was often attached to one of the reins, for example on a pair from Manching in Bavaria (Jacobi 1974, 270, no. 15, Taf. 3). Plate couplers with a series of perforations permit the clamping of different thickness of metal, but they have seldom been recognised from any archaeological period unless attached to one of the reins. A plate coupler with three perforations is known from Cirencester, Glos, of Roman date (Manning 1985, 6), and a few of later date are known from the Continent (Ohlhaver 1939, Abb. 31). However, coupling devices were not always attached, possibly because this proved inconvenient in use - but they may then have been prone to loss. Tongs and coupler No. 40 are from a burial.

Some of the complete tongs may have a very slight difference in the lengths of the two reins, but this is more noticeable in No. 33, and in addition, the longer rein is tapered. It seems very possible that the reason for this was to enable the use of a coupler.

Small tongs

Two small tongs, Nos 41 and 42, occur in a hoard of tools and scrap metal which probably had belonged to a non-ferrous metalworker. The small tongs No. 43 have unusual circular flat gripping faces. According to the X-radiograph, the ends are continuous with the jaws rather than having been 'welded on' (cf. Fox 1946, 96).

Chronology

No. 38 is (C-14) dated by associated material to the second century BC. No. 40 is from a first century BC context. Tongs Nos 33-37 are associated with late first century BC or early first century AD date artifacts in a hoard. Nos 41 and 42 are associated in a hoard with artifacts of first century AD date including Iron Age types and Claudio-Neronian types. Nos 39 and 43 are from a probable multi-phase deposit; on the basis of associated artifacts they may date anywhere between the second century BC and the mid-first century AD. The context of No. 44 is not known but is possibly fifth to third centuries BC.

Metalworking associations

As noted earlier, tongs Nos 33-37, and Nos 41 and 42 are from hoards containing other metalworking tools; the latter two are associated with scrap non-ferrous metal. No. 40, from a burial, has a small piece of ferrous slag attached.

Other relevant associations

Tongs Nos 33-37, and Nos 39 and 43 are from probable ritual deposits from Waltham Abbey and Llyn Cerrig Bach respectively. Tongs No. 38 were found with pokers Nos 1 and 5 beneath a grain silo at Garton Slack. Tongs No. 40 are from a burial at Rudston, North Humberside.

3.4. **Anvils and stakes**

Nos 45 - 54. Figs A6 - A7. Metallography S7 - S9.

Date category *A*: 46, 48, 51, 52, 54. *C*: 47. *D*: 45, 49, 50. *E*: 53.

During the Bronze Age, well-formed and complex cast bronze anvils were used (Ehrenberg 1981). Few of the known Iron Age anvils are as elaborate despite anvils and stakes probably having been employed during the majority of basic forging processes. It is possible that some stakes, mandrels, and other formers may have been made from hard wood shaped for special needs (cf. Sellwood 1984, 359), or that natural forms such as antlers may have been employed.

Stone anvils

Possible stone anvils have been found in association with early furnaces and hearths; these may have been used for the fettling and consolidation of iron blooms. At Kestor, a stone anvil was found near a small iron-smelting furnace and a possible forging pit, and a hammerstone was found close by (Fox 1954, 39-40, 59-61, fig. 9; Tylecote 1962, 195). The anvil, which is a fine-grained granite boulder, has an undulating top and shoulders and shows much evidence of wear (Fox 1954, 39, 56-7, pl. XI, B). The iron smelting and smithing site at Bryn y Castell has yielded three stones, each with a worn surface with impacted iron slag, and at least one of these stones had been used an anvil (Crew 1987, 98, pl. 5). The stones are from Site A, but none was found *in situ*. Archaeomagnetic dating indicates ironworking at Site A (the second phase of the site) extended from the earlier first century AD to the third century AD (Crew 1987; 1989). No iron tools were found in the areas of pre-Roman activity, nor from Site A, and it may be that stone tools were in normal use throughout the duration of metalworking activity at this site. A possible stone anvil and a hammerstone were found at the Iron Age smelting and smithing site at Crawcwellt (Crew 1989).

Iron anvils

For the forging and shaping of hot or cold metal, it would seem preferable to use anvils made of metal which would be less likely to fracture from impact, and could be shaped to suit a multitude of functions. The iron anvils known from the Iron Age are:

(1) Two block anvils and a probable third

(2) Three stemmed anvils with beaks, and fragments of two others

(3) Two possible bench anvils.

In addition, there are other blocks of iron which may have served as anvils, and these are discussed with the block anvils.

(1) Block anvils

The block anvils, Nos 45 and 46, may have been used free-standing, or set into supports in order to secure them more firmly and to create the right working-height. The stem of No. 45 is shaped as if for insertion into a block, and through the lower stem there is an oval hole which may have served as a punching-hole (Manning 1985, 1), or possibly as a means of securing it more firmly to a support. Anvil No. 46 is heavily concreted, but the X-radiograph suggests that there is a loop at the base. The simplest explanation for the holes in the bases of these two anvils is that a clamped or weighted pole was passed through the hole in order to secure the anvil firmly.

Another block anvil (not catalogued), from Sutton Walls (Kenyon 1953, 23, pl. XVIa), was considered by the excavator to be pre-Roman, but the circumstances of recovery cast some doubts on this attribution. Clearance by bulldozing had disturbed its original position. It is of immense size and weight (50kg), and has two vertical grooves which may have been used for drifting, punching, or for heading large nails (Tylecote 1961). It is generally considered that this anvil is a Roman form (Tylecote 1961, 56; Saunders 1977, 15; Manning 1985, 1), paralleled by one from Stanton Low, Buckinghamshire (Manning 1969, 580, A3; Tylecote 1987, table 7.5, fig. 7.13), and many examples from the Continent (Manning 1985, 1). Unfortunately, the context in which the Sutton Walls anvil was found gives little assistance for dating, due both to the circumstances of recovery, and to the possibility that the anvil may have sunk during burial owing to its great weight. The excavations produced much Roman material from nearby features, and thus a Roman date is not improbable.

Like Nos 45 and 46, early block anvils from the Continent suggest that the Iron Age examples were much smaller than the Roman ones, and none have slotted punching holes (nor recesses for anvil tools). These include two from Byciskála-Höhle in Moravia (Ohlhaver 1939, 115; Pleiner 1962, fig. 10, 4 and 5), one from Heidetränk, Germany (Müller-Karpe and Müller-Karpe 1977, 54, Abb. 5, 14 and 18), and one from Szalacska, Hungary (Darnay 1906, 423, fig. 17).

<u>Other iron blocks</u>

A number of sites have produced blocks of iron which taper from a roughly flat, square or rectangular face, to a hooked base (Table 3:1). These blocks have been variously described as earth anvils (Gray and Bulleid 1953, 244; Macgregor and Simpson 1963, 396; Coghlan 1977, 69), weights (Coles 1987, 123), steelyard weights (Spratling 1979, 104), and possible metalworkers' anvils (Ehrenreich 1985, 33). Iron billets are another possibility (R. Jackson pers. comm.).

There are arguments both for and against the use of these blocks

Table 3:1 Hooked iron blocks

Site	Weight g	Length mm	End face mm	Source
Barbury Castle	1010	143	54 x 54	Appendix A, No. 46
Gussage All Saints	1589	124	60 x 36/34	Wainwright 1979, 104, no. 1019, fig. 80
Hod Hill	1553	156	61 x 29	British Museum P1975 7-1 6
Hunsbury	1242	134	59 x 38	Northampton Museum D144 1957-8
Meare Village East	1360	144	42 x 42	Coles 1987, 123, 139, fig. 3.50
Meare Village West	1150	140	44 x 36	Gray & Bulleid 1953, 244, I28, pl. LI
Meare Village West	1690	173	61 x 36	Gray & Bulleid 1953, 244, I32

as anvils, discussed below. The example from Barbury Castle seems likely to have been used for metalworking and this one is therefore included in the catalogue (No. 47). Although associations are uncertain, this block may possibly belong to a hoard of metalworking tools and scrap metal (Chapter 5.4e).

The term 'earth anvil', synonymous with 'field anvil' and the preferred term 'mowers anvil', is more properly reserved for the winged anvils which do not appear in Britain until the Roman period (Manning 1964, 55). These were used by workers in the field to re-sharpen scythe blades by cold-hammering (Rees 1979, 480-2), though as Coghlan points out, mowers' anvils may also be used by smiths for light work (Coghlan 1977, 69). These types of anvil are wedge-shaped blocks or pegs, pointed for insertion into the ground, with wings or a plate to prevent the anvil from sinking under impact. The identification of the hooked blocks as mowers' anvils may therefore be incorrect, particularly since none have wings. Gray and Bulleid (1953, 244) presumed that the hooked bases of the two from Meare Village West had been bent through damage, and that they had originally been straight and pointed for driving into the ground. MacGregor and Simpson (1963, 396) also concluded that the tip of the Barbury Castle anvil (No. 47) was damaged (and oddly they have illustrated their 'earth anvil' upside down). However, the face of this one is domed, well-burred at the edges, and much dented by use, which indicates that it had been used for considerable hammering.

It seems unlikely that these hooked blocks were weights owing to an off-centre lean of between about 10 and 20 degrees when they are suspended by their hooks. In general, the blocks appear to be of relatively similar shape, the broad end-faces are roughly flat, though some appear to be formed of poorly welded blooms. The one from Hunsbury has debris and iron slag covering the end face, but this too appears to be poorly welded, and part has fractured off. Nevertheless, metalworking anvils such as the one from Sutton Walls, also appear to have been made from poorly welded blooms. It is difficult to envisage the role of the hook if the blocks were indeed anvils and, if the hook was intended to anchor the anvil, how this functioned. Some indication may come by comparison with the two block anvils discussed above, No. 45 with a hole through the base, and No. 46 with a loop at the base. Conceivably, a pole or other anchoring device was passed through the hook to steady the base in earth or in another support, with the flat end-face uppermost.

On balance, there is a possibility that these blocks may have been used as mowers' anvils, metalworkers' anvils, or possibly for another purpose, but at present identification remains uncertain.

Another iron block, but this one circular and weighing 7kg, from Oldbury Hill in Wiltshire, was originally described as a 'pig' or ingot of iron (Cunnington 1887, 217; Cunnington and Goddard 1934, 147, 237, pl. LXXX, 3; Manning 1969, A7). This may well have been an anvil; its dating is uncertain and it is as likely to be Roman.

(2) Stemmed anvils

The three stemmed anvils with beaks, Nos 48-50, were multi-purpose forming tools which may have been used in a variety of positions. Anvil No. 48 is plain whereas the Nos 49 and 50 have swage grooves on their rear faces. No. 49 also has three depressions which may have been for shaping metal; two on one of the side faces, and the third on the opposing side. If supported in different positions, these anvils offer flat surfaces and a variety of curved surfaces for the forming of metalwork, beaks and stems for shaping curves, as well as swages and depressions for fine shaping (Section 3.5). Other possible stemmed anvils are Nos 51 and 52.

(3) Bench anvils

The possible bench anvils Nos 53 and 54 may have been used as stakes for working small items of metalwork. Both of these tools, in particular No. 53, may also have served as punches. Two similar tools, identified as anvils, are known from Manching in Bavaria (Jacobi 1974, 271, pl. 4, nos 27 and 28). The first one from Manching is hexagonal in cross-section and hence very like No. 54. Another tool of similar form, queried as a bench anvil, but of Roman date, is from Verulamium (Manning in Frere 1972, 163, fig. 60, 1). Small anvils such as these may have been mounted or clamped vertically in a support such as wood, and may also have been used as mandrels if mounted sideways on.

The surviving anvils demonstrate that the Iron Age metalworker used a range of types, from simple bench anvils to complex stemmed anvils. Although no Iron Age T-shaped stakes, L-shaped stakes, or mandrels have been recognised in Britain, they are known from the Continent, for example at Manching, Bavaria (Jacobi 1974, 271, Taf. 4, nos 21-23 [short L-stakes], no. 24 [T-stake], no. 25 [horned T-stake]) and Szalacska, Hungary (Darnay 1906, 423, fig. 18 [double-beak]).

Chronology

No. 54 is potentially associated with fourth century BC tools in a hoard. Anvil No. 46 is from a second century BC context. Nos 47, 48, 51 and 52 are broadly assigned to the later Iron Age. Anvils Nos 45, 49 and 50 are associated in a hoard with late first century BC or early first century AD artifacts. No. 53 dates to the mid-first century AD and may be post-Iron Age.

Metalworking associations

Nos 48 and 52 are from possible metalworking areas at Meare Village East (Chapter 5.2.5). No. 46 was found upright set into natural clay at Bigbury, in an area though to have served as a temporary ironworking smithy on the basis principally of this anvil (Thompson 1983, 251-2). Nos 45, 49, 50, 54, and possibly No. 47, are from hoards of ironwork which included other metalworking tools.

Unlike some of the Bronze Age anvils (Ehrenberg 1981, 20-1), none of the Iron Age anvils has evidence of copper alloy ingrained in their working faces, though No. 45 has traces of possible hammer scale and haematite on the face and sides.

Other relevant associations

Nos 45, 49 and 50 from Waltham Abbey, and No. 54 from Fiskerton, are from possible ritual deposits of ironwork which included metalworking tools and woodworking tools.

Metallography

It has been estimated that blooms from early furnaces would have weighed only 1kg or so, though the prepared billets would have weighed considerably less (Tylecote *et al.* 1971, 342). The larger blocks and anvils were therefore probably made by welding together more than one bloom. Metallography of two of the hooked blocks, No. 47 (S7) and the one from Hunsbury (Table 3:1), S63, revealed heterogeneous low-carbon iron of low hardness. In structure they are not unlike the Sutton Walls anvil (Kenyon 1953) which had been made by welding porous blooms of slightly higher-carbon content (Tylecote 1961, 57-60).

No. 54 (S8/S9) was made from ferritic iron and was relatively soft. There is evidence of cold-working at the head. Although it is surprising that it had not been made from hardened steel, perhaps a more resilient and less brittle tool was preferred.

3.5. Swages and 'moulds'

Nos 49, 50, 55, 58. Figs A7 and A8. Metallography S10.
Date category *A*: 55. *D*: 49, 50, 58.

Swages are known on anvils from the Bronze Age, which are in the form of channelled grooves on the face or sides of the anvils (Ehrenberg 1981, nos 9, 14, 16, 24, 30, 35 and 36). Their purpose was probably similar to modern swages, which are used typically to shape rod or to create a groove in sheet metal (Untracht 1982, 248-9). Some of the Bronze Age anvils have small depressions or holes which may have been intended to assist perforating sheet metal, or used for 'moulding' sheet metal (Ehrenberg 1981, 20). If these were moulds, in modern usage they would correspond to doming blocks for creating hollows and other shapes when used in conjunction with suitably shaped punches.

Few swages and 'moulds' have been recognised from the Iron Age and Roman periods in Britain (Manning 1985, 4), possibly because tools in wood were employed for many purposes, and these do not survive under normal burial conditions. Experimental reconstruction of a torc from Ipswich led Brailsford and Stapley (1972, 232-4) to suggest that a single pair of octagonal swages, perhaps of wood, had been employed to form the faceted wires. Swages and 'moulds' seem to be rare also on the Continent, though a hoard of late Iron Age (La Tène C/D) tools from Lozna, Rumania contained an anvil with two swage grooves and a hammer with twelve depressions (Teodor 1980, Abb. 5 nos 3 and 5).

The form of a swage or a mould determines the shape of the metal which is forced into contact with its surface (Untracht 1982, 248). Metal is hammered into a bottom-swage, whereas a top-swage is struck on to the metal. Today, swages are sometimes used in pairs, a lower bottom-swage in combination with an upper top-swage. The cross-sectional shape of rod may be altered by hammering it between a pair of swages, or into the channel of a bottom swage. The former method is more appropriate for the hot forging of iron (Andrews 1977), whereas the latter method tends to be used for cold metal (Untracht 1982).

The only probable Iron Age swages from Britain have grooves of approximately semi-circular section. A pair of grooves are incorporated on the rear faces of both of the two stemmed anvils (Nos 49 and 50) from Waltham Abbey. The hoard also includes a hammer (No. 58) with a groove across one face and another on the side of the hammer. Manning suggests that the grooves on the hammer were the top-swages corresponding to one of the grooves on each of the anvils, which, if used in pairs would enable the production of round-sectioned rod (Manning 1980, 93; 1985, 4). Manning further suggests that the original tool set probably contained a second swage-hammer, to correspond with the two other grooves on the anvils.

Another possible top-swage is No. 55 which has a 4.5mm long groove at the tip. This may have been used for forming short lengths of round-sectioned rod, perhaps in conjunction with a bottom-swage. Alternatively, this may have been a chasing tool for forming high relief, although the relatively sharp edges make this rather unlikely.

Anvil No. 49 has two depressions on one side and a third on the opposing side. All three depressions are approximately semi-circular in section, and their outlines are round, oval, and kidney-shaped. It seems very possible that these were intended as 'doming' holes, though other functions are possible.

<u>Chronology and associations</u>

Anvils Nos 49 and 50 are discussed in Section 3.4; hammer No. 58 is discussed in Section 3.6. Top-swage No. 55 is from a hoard of metal-working tools and woodworking tools, possibly a ritual deposit, and may date to the fourth century BC.

Metallography

A sample of corrosion products from No. 55 revealed residual carbides suggesting a moderate to high carbon content and that its original structure was not quench-hardened.

3.6. **Hammers**

Nos 56 - 89. Figs A8 - A12. Metallography S11 - S37.
Date category *A*: Nos 60, 62, 69, 71, 73, 74, 77, 78, 82, 84, 86, 87, 89. *B*: No. 67. *C*: Nos 59, 61, 63, 66, 68, 70, 72, 75, 76, 81, 83, 88. *D*: Nos 56, 57, 58, 64, 65, 79, 80. *E*: No. 85.

Before discussing the iron hammers, the evidence for the use of hammers on Iron Age metalwork is considered, and in addition, hammers in stone and in organic materials, and the use of hammers in other crafts.

Use of hammers on Iron Age metalwork

Evidence for the use of hammers on metalwork derives largely from inferences from tool marks and the structural form of artifacts.

On Bronze Age metalwork, shallow oval tool impressions and some elongated tool marks are generally assumed to have been produced by metal hammers (e.g. Rowlands 1976, 15, fig. 1; Gingell 1979, 246). The hammers known from the Bronze Age in Britain are principally from hoards of bronze and scrap metal, many of which are considered to be metalworker's hoards (e.g. *Inventaria Archaeologica* GB 6:6, 17:34, 18:22, 18:23, 41:5, 41:6, 43:15). In general, these socketed hammers have broad and slightly convex faces, though on the Continent a wider range is known (Ohlhaver 1939, Abb. 6; Jockenhövel 1982, Abb. 2). Socketed iron hammers, with rectangular or round faces, are also known on the Continent from late Hallstatt and early La Tène contexts (Spehr 1975, Abb. 6; Hennig 1986).

On Iron Age metalwork, tool marks which are presumably from the use of hammers occur on copper alloy billets (e.g. Clarke 1951, 223, pl. XIXb; Stanford 1974, 162, fig. 74, 17; Davies and Spratling 1976, 135, fig. 10, 31; Spratling 1979, 130, fig. 98, 1) and part-manufactured items (e.g. Davies and Spratling 1976, 135, fig. 10, 32; Stead and Rigby 1986, 122, no. 162, fig. 162). Occasionally tool marks from manufacture are visible on finished products, for example on shield mounts (e.g. Stead 1985a, 10) and vessels (e.g. Cunliffe 1988, 27), and on altered items such as the possible cut-up sword from Battlesbury Camp, Wiltshire (Devizes Museum). The relative thinness (sometimes much less than 0.5mm), and comparative evenness of some large sheet metal artifacts suggests that a considerable amount of skilled forging of metal was often undertaken (e.g. Jope 1971; 1976; Spratling 1970b; 1972).

A bronze vessel fragment from Potterne, Wiltshire (C. Gingell forthcoming), dating to around the seventh century BC, has three different types of tool marks (Plate IIIb). Over the whole fragment are elongated impressions, and smaller oval impressions with three raised marks (Plate IIIb, circled), the latter presumably produced by a damaged tool. Aligned with the curve of the rim are very narrow elongated marks (arrowed in Plate IIIb). No metalworking tools were found in the midden at Potterne, and the tool marks on the vessel need not have been produced by an iron hammer. Nevertheless, they demonstrate that at least three different tools, probably all hammers, had been used in the production of the vessel - one clearly leaving its 'signature'.

Some methods of working may not have employed hammers, and tool marks do not always assist in attribution of the technique or tool. For example, some decorative tool marks may equally have been applied by hammering or by the use of a punch (e.g. Stead 1984a, 49, pl. II, a; Coles 1987, 72, E81).

The structural form of some Iron Age artifacts, sometimes in conjunction with tool marks, suggest that techniques such as raising and sinking were probably employed. In particular, this applies to three-dimensional forms made from a single sheet of metal, such as the body of vessels, and shield bosses of tight curvature. Hammer marks on the reverse sides of some Iron Age shield mounts, such as those from the Thames at Battersea and Wandsworth (Jope 1970, nos 247 and 253), suggest that they may have been shaped by sinking (Spratling 1972, 259, nos 305 and 321; but cf. Stead 1985a, 10). Three convex disks from Mount Batten, Devon with hammer marks on the inside (Cunliffe 1988, 27, nos 14, 15, 17), two of which have concentric hammer marks, may have been formed either by blocking or by sinking, and from the written description the latter technique seems more likely. Spratling cites other examples of bowls which are very likely to have been created by sinking (Spratling 1972, 259, nos. 385, 389, 390, and no. 397 exported), whereas the lower part of the cauldron from Santon, Norfolk was probably raised (Spratling 1972, 259, no. 429).

Shield mounts may have been shaped over the wooden mounts using a combination of raising to compress the metal over the wooden bosses and spines, and blocking or sinking to achieve the low angles (Spratling 1972, 259, cf. nos 308, 310, 313, 318, 319). Wooden patterns, however, would have been unsuitable for the shaping of shield mounts with undercuts (e.g. Savory 1964, 452-4, no. 1, fig. 2), or vessels of tight curvature, owing to the need to frequently anneal the metal (Maryon 1949, 99).

The techniques of raising and sinking require close control - one hand to steady the workpiece and the other to wield the tool (Maryon 1949). It seems a fair assumption, therefore, that hammers were employed for these techniques - techniques which themselves are assumed. Unless tool marks are clearly visible, it is often difficult to determine if artifacts had been produced by raising, sinking, or by blocking. Tool marks from these techniques, like those from forging, were presumably often removed or softened by planishing (cf. Stead 1985a, 10) or by hand polishing. Small circular vessels from the later Iron Age were sometimes polished on a wheel (Watson 1949; Voce 1951; Spratling 1972, 259, nos 385, 389, 390, 397, 400, 402).

It is relevant to add that because the size of a hammer mark depends on the force applied, the impressions formed are therefore not usually indicative of the size of the tool face (contra Maryon in Singer *et al.* 1954, 636), unless a flat hammer is used on flat metal.

Uses of hammers for metalworking other than forging and forming may have included decorating, mechanical joining (e.g. riveting, or folding seams), cold-working to harden and strengthen, as well as striking other tools.

Uses of hammers in other crafts

Hammers or mallets may have been used for the striking of tools, for example in woodworking, stone-working, and leather-working. Large hammers may have been used during quarrying, mining, and ore preparation. Although the archaeological evidence suggests that nails were seldom employed during the Iron Age, presumably hammers (or mallets) were used in construction work.

Stone hammers

Stone hammers are known from Kestor (Fox 1954, 39, 56-7, pl. XB), Bryn y Castell (Crew 1987, 98, pl. 5), and Crawcwellt (Crew 1989), and these are mentioned earlier in connection with the preliminary forging of iron blooms (p. 16 and p. 95)

Mallets

Today, mallets made from fine-grained or compact organic material such as wood, antler, horn, or leather, are sometimes used for shaping and flattening metal (cf. Untracht 1982, 248, fig. 6-238). According to Maryon (1971, 91), wedge-shaped raising mallets made of horn are used today in Italy by coppersmiths; in other countries their use is in any case often preferred during certain raising processes (Loyen 1980).

A few mallets have survived from the Iron Age, but none can be assigned a definite metalworking function. Those of suitable dimensions for use on metals are all made from antler, for example from Glastonbury (Bulleid and Gray 1917, 435-40, pls LXIV, LXV, LXVIII), Meare Village East (Coles 1987, 89, H5, 97, H88, fig. 3.25), Bredon Hill (Hencken 1938, 86, fig. 12, 1) and Hunsbury (Fell 1936, 73, no. 17). The faces of these mallets are large and flat, and thus would only be suitable for basic shaping or flattening techniques, though none need have been connected with metalworking.

The iron hammers

Possible classification systems of hammers are by: (A) weight, (B) overall form, (C) shape of faces. These properties are considered first, before discussing the hammers under principal types.

(A) Weight

The simplest means of classifying hammers is by weight. Hammers over about 2kg are usually considered to need the use of two hands and are thus normally classed as sledge hammers (Andrews 1977, 24). Modern hammers range in weight from 30g for fine working to 300g for working pre-formed sheet non-ferrous metal (Cooper n.d.), and upwards from 200g for iron-smithing (Bealer 1969).

The majority of the medium- and small-sized Iron Age hammers are too corroded to enable useful comparison of their weights. The present weights of the hammers are shown in Table 3:2 with an estimation of the possible weight error.

(B) Overall form

The majority of the hand hammers are swollen laterally about the eye, but in a few, the sides are straight. In the latter, the centre of

No.	Hammer form	Length mm	Weight g	FACE 1: LEFT* form	dimensions	FACE 2: RIGHT* form	dimensions	LxW$	EYE hafting	wedges
56	straight	153	852 ++	■ bc	61x58	■ bc	55x56	50x30	no	no
57	straight	≈	≈	≈	≈	■ c	32x45	-	-	-
58	straight	123	1553 +	■ bc	44x48	■ bc	45x45	36x16	yes	no
59	curved	124	844 ++	▬ bc	22x19	▮ bc	36x47	40x24	no	no
60	straight	102	381 ++	▬ c	18x12	▮ c	13x25	40x12	no	no
61	arced	≈	≈	▬ b	23x8	≈	≈	27x13	yes	2
62	arced	180	476 +	▬ c	27x9	▬ bc	27x16	40x10	yes	2
63	curved	120	326 +	▬ c	25x10	■	19x19	25x17	no	no
64	straight	128	174 +	▬ c	14x5	■ b	17x20	28x8	no	no
65	angled	86	130 +++	■ b	14x17	— c?	17x6	17x7	?	2
66	curved	119	92 ++	— c	13x2	■ c	10x11	21x5	yes	1
67	straight	111	142 ++	— c	8x2	■	13x13	25x13	yes	3
68	straight	104	132 +	▬ c	15x9	■ b	16x16	21x11	(no)	(no)
69	?	94	-	-	-	▮ ?	-	-	no	no
70	straight	89	-	▬ ?	-	▬ ?	-	-	-	1
71	arced	183	70 +++	— bc	11x5	● c	10	15x5	no	no
72	arced	143	43 +++	— c	9x3	● c	5	15x6	no	no
73	arced	136	40 ++	— c	8x2	● bc	10x8	19x4	no	no
76	arced	101	40 +++	▬ c	8x4	● c	7	16x4	no?	no
77	arced	90	34 ++	▬ c	8x4	▬ c	8x5	14x5	no	no
78	straight	82	≈	—	5x1.5	■	6x4	8x5	yes	no
79	arced	60	20 +++	— c	7x1+	■	7x7	8x7	no	no
80	angled	82	50 ++	▬ ?bc	11x6	▬	8x6	19x8	no	no
81	angled	66	42 +++	▬ bc	?11x6	▮ bc	?8x11	18x8	no	no
82	angled	73	43 +++	■ b	8x8	▮	7x10	14x8	yes	2
83	angled	77	60 +++	■ bc	?10x10	▮ bc	?6x10	17x4	no?	no?
84	curved	58	17 +++	▬ bc	8x7	■ bc	9x10	31x7	yes	no
86	curved	82	172 ++	■ c	18x17	▮ bc	14x18	27x8	no	no
87	straight	≈	≈	- b	-	≈	≈	-	no?	no?
88	straight	87	-	< ▮ ?	10x13	●	12	12x12	-	no
89	straight	65	49 ++	▬ c	10x8	■ bc	9x9	20x6	no	no

* As illustrated in Figs A9-A12; dimensions in mm rounded down (behind burr). - Not known.
Nos 74, 75 and 85 excluded. ≈ Missing: not given if incomplete. $ mm, rear.
+ Substantial metal core, slight corrosion, minor weight error ++ Substantial metal core, but greater corrosion, weight error ?<30%; +++ Little or no metal core; weight not representative of original artifact. ■ Square ● Round — Narrow cross pein
▬ Broad cross pein ▮ Broad straight pein b Burred c Convex

Table 3:2 Hammers: summary of principal features the hammer is thickened above the eye. The reason for the differences in form is probably the method of manufacture coupled with the need to maintain strength at the eye (to absorb impact shock). In hammers where the eyes are central, it is likely that these were normally made by punching and drifting a hole (e.g. Pleiner 1962, fig. 39B), attested in some by visible metal stringers (Nos 63 and 68), or by X-radiography (Nos 72, 73, 77). Thus the excess metal from forming the eye is expanded around the eye, or is accommodated above the eye if the hammer sides are made straight.

The Iron Age hammers may be divided into the following basic overall forms: straight, arced (or curved), and angled (Fig. 3:2b).

Dimensions of hammers, like weight, may reflect scale of work. In addition, some hammers may have been made long to enable reach, or curved to enable access in or over a workpiece (cf. Untracht 1982).

(C) <u>Shape of faces</u>

The action of the hammer during forging, raising, and other techniques which deform and displace metal depends on the shape of the hammer face and the angle of impact (Untracht 1982, 247). A flat-faced or fully convex faced hammer spreads the metal in all directions radially from the point of impact if struck squarely on to the metal. A rectangular face spreads the metal in a direction perpendicular to the length of the hammer face. Thus, a straight pein (Fig. 3:2a), with the shaped working face lying on the same axis as the handle, spreads the metal sideways, whereas a cross pein spreads the metal in length (cf. Pleiner 1962, figs 40, 44, 45 and 46). Furthermore, if the pein is struck at an angle to the metal, for example during raising, the metal flows in the direction of the impact angle (Untracht 1982).

The principal shapes and curvatures of the faces of the Iron Age hammers are shown in Figure 3:2, c and d.

Some of the smaller (i.e. hand) hammers have common attributes (Table 3:2), of which overall form and shapes of faces may correlate with function. A number of the hammers may have had very specialised purposes. However, the majority have two very different types of faces, suggesting that they were not only multi-purpose tools, but that possibly some faces were used for a variety of very different purposes.

The Iron Age hammers are discussed under two broad categories

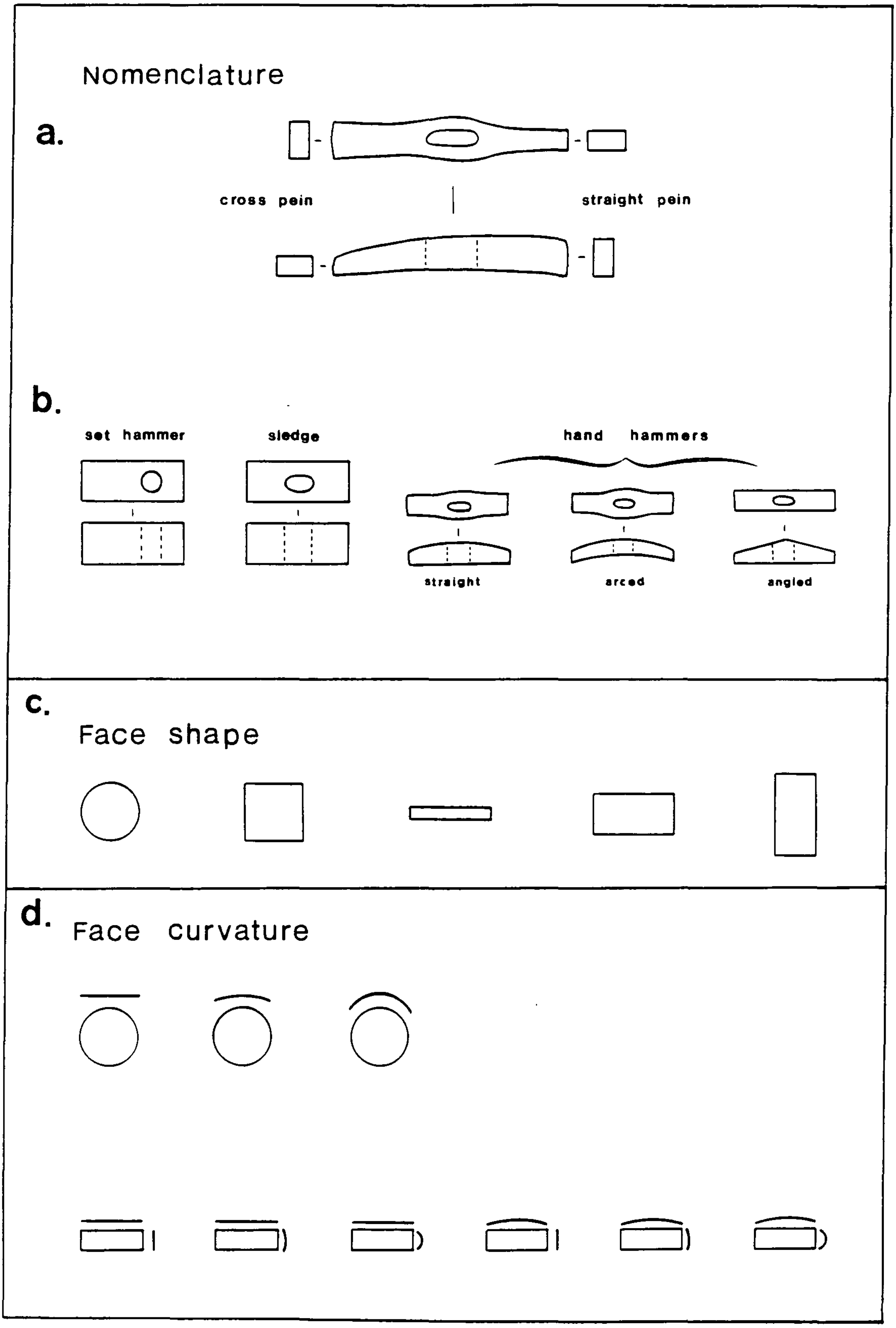


Figure 3:2 Diagrams of principal types of Iron Age hammers: form and nomenclature

(*I* sledge and struck hammers, and *II* hand hammers) according to scale and thus usage, and are sub-divided as appropriate.

I. Sledge and struck hammers

It is unlikely that any of the known Iron Age hammers were made solely for use as sledge hammers, though Nos 56-58 may have served this purpose. Their prime use was probably as forging tools.

Nos 56 and 57 are possible set hammers (cf. Saunders 1977, 16), both are from a possible hoard of ironwork from Bulbury, Dorset.

In modern usage, set hammers are iron-forging tools which are struck with a second (sledge) hammer, allowing greater control of the work than if a single hammer is used (CoSIRA 1955, 12; Bealer 1969, 92-3). In general they are used to finish and 'set' forgings (Andrews 1977, 28; Saunders 1977). The eye is characteristically off-set towards one end.

Hammer No. 58 has two swage grooves (Section 3.5); one on the face, which was presumably used as a top swage when struck with a sledge hammer, and another on the side of the hammer.

II. Hand hammers

Hand hammers are divided into the following classes based on the face shape, with some of the hammers occurring in more than one group:

(a) Hammers with one or more cross peins

(b) Hammers with one round or ball face (paired with a cross pein)

(c) Hammers with one straight pein (paired with a cross pein or square face)

(d) Hammers with two broad, round or square faces.

(a) Hammers with one or more cross peins

Hammers Nos 59-73 and 76-81 have at least one distinct cross pein, with the second face being one of the following:

(1) A narrow cross pein (Nos 77 and 78)

(2) A medium (Nos 69 and 80) or broad cross pein (No. 62)

(3) A straight pein (Nos 59, 60, 65 and 81)

(4) Square (Nos 64, 66, 67, 68, 79, and No. 63 (?single-faced)

(5) Round (Nos 73 and 76) or ball-faced (Nos 71 and 72), or possibly pointed (No. 70).

The cross peins of Nos 59 and 81 are heavily burred, and Nos 61 and 71 are very slightly burred.

Some hammers in this group have common and very distinctive attributes which are presumably related to function (there are no geographic or chronological correlations). From the evidence discussed earlier for the use of certain forming techniques in the Iron Age, it seems likely that hammers may have been made for specialised purposes. Possible functions are offered below on the basis of properties required in tools for the equivalent working methods and techniques today. However, for the reasons discussed in Chapter 2, the similarity of these tools to recent and modern examples may not necessarily reflect purpose during the Iron Age. Identifications are therefore provisional.

(i) The large hammers Nos 59 and 60, both with two broad rectangular faces - a cross pein and a straight pein - were possibly general forging hammers offering the option of broadening or lengthening the metal depending upon which face was used.

(ii) Raising is the technique by which flat sheet metal is shaped in to a three-dimensional form by compressing the metal on to a suitably shaped stake (Maryon 1949; Loyen 1980). It seems very likely that the technique was used in the Iron Age (cf. Spratling 1972).

Today, the metal is normally worked concentrically from the outside of the curvature and sometimes the basic form is initiated by 'blocking' the sheet metal into a recess in a wooden block (Maryon 1949, 95-8, figs 5-9; Loyen 1980, 27, 63). Modern raising hammers are often elongated for reach, and arced along the longitudinal axis with the faces inclined towards the handle. The faces are typically rectangular, and convex over their length, but they can be in many other forms (cf. Untracht 1982, fig. 6-234). The front edge of the face (i.e. the edge away from the handle) strikes and compresses the metal to the anvil, and is therefore well-rounded.

On the basis of length, curvature, and the shape of one face, two of the Iron Age hammers (Nos 61 and 62) may very possibly have been intended for raising. Both are medium-sized hammers and thus suitable for forming relatively substantial forms from thick sheet metal, and both were quench-hardened (p. 115-7). The cross pein on No. 62 is paired with a much burred, broad cross pein which possibly was used for forming sheet metal. (No. 61 is fractured across the second face.) Compare also hammers from St. Georgen, Austria (Taus

1963, 14, Abb. 2), Heidetränk, Germany (Müller-Karpe and Müller-Karpe 1977, 54, Abb. 6, no. 2), and Sanzeno, Nonsberg (Nothdurfter 1979, 36, Taf. 15, nos 259 - 264).

Other hammers which may possibly have been used for raising are Nos 71-77, and conceivably Nos 63, 64, 66, 67, 68, 70 and 80. The former group are slender hammers and are discussed below as possible sinking hammers. The latter have little or no curvature over the lengths of their bodies, though this may not be a necessary attribute to enable raising.

(iii) Sinking is another method of producing three-dimensional forms, but the technique differs from raising in that the metal is stretched (rather than compressed), and in general the metal is worked from inside the curvature (Maryon 1949, 94-5; Loyen 1980, 70). Modern sinking hammers are usually long and slender to enable access, and, like raising hammers, are often arced along the axis with the faces inclined to the handle. Typically they have small convex faces which are cross-peined, round, or ball-peined (Loyen 1980).

Three of the Iron Age hammers seem very possibly to be sinking hammers: Nos 71, 72 and 73. All are long and slender, and each has a narrow rectangular cross pein and a round or ball face. Other examples may include Nos 76 and 77. These five hammers may have been used also for raising or for other purposes; perhaps they were used interchangeably for several techniques - their distinct form suggests very specialised function(s). Nos 71, 72, 73 and 76 were quenched whereas No. 77 was not (p. 115-7). Conceivably Nos 74 and 75 (both now lost) may be included in this group, providing analogies made at the time of discovery or soon afterwards can be believed.

(iv) Planishing hammers are used today to remove prior hammer marks such as those produced during forging non-ferrous sheet-metal and during raising. Typically they have faces which are flat or slightly convex, and well-smoothed (Untracht 1982, fig. 6-234, 5).

It is uncommon to distinguish planishing marks, though they have occasionally been found on Iron Age metalwork, for example on a shield mount from Battersea (Stead 1985a, 10; contra Spratling 1972, 259).

The rounded faces of hammers Nos 66, 73, 76, and possibly cross peins of other hammers, may conceivably have been used for planishing.

(v) Tool marks sometimes indicate the use of narrow cross peins (or

possibly punches) though it is not always clear the function of the tooling. Some tool marks may have been applied for decoration; in other cases they may be incidental from work-hardening the metal, or from shaping or joining metals, or joining metal to other materials.

The tiny hammer No. 79 was presumably made for a special function, possibly for the closing of small rivets. The slender hammer No. 78 must also have had a particular function. It is paralleled in overall form with one from Celles, Cantal, France (Pagès-Allary *et al.* 1903, 397, no. 20, fig. 23), though that has five points at one end, possibly to serve as a decorating tool and conceivably for leather-working (Guillaumet 1982). However, No. 78 is from a burial which, apart from weapons, included tongs (with ferrous slag attached), suggesting that the burial was connected with metalworking.

(b) Hammers with one round or ball face

Hammers Nos 73 and 76 have small round convex faces, and Nos 71 and 72 have small ball peins. All are paired with narrow cross peins. These are arced slender hammers and may possibly, therefore, have been sinking or raising hammers; the former two may have been for planishing.

(c) Hammers with one staight pein

Nos 59, 60, 65, 81, 82, 83 and 86 all have a single broad rectangular straight pein, the first four paired with narrow or medium cross peins, the latter three paired with square faces. It seems likely that the straight peins of these hammers may have been used for general drawing down, thus offering the option of broadening or lengthening the metal depending on which face was used. Nos 59, 65, 81 and 83 are heavily burred.

(d) Hammers with two broad round or square faces

Hammers Nos 86, 88, 89 and possibly Nos 85 and 87, have broad, round or square faces. These were possibly general-purpose hammers, perhaps for striking other tools. No. 88, has two large rounded faces and was originally described as a bridle cheek-piece (Hawkes and Hull 1947, 343), and is not unlike the 'toggles' from the Polden Hill Hoard, Somerset (Brailsford 1975, 230, nos 7 and 8, fig. 6k). Although X-radiography suggests that this may be a hammer with two thickened faces, detail is obscured by accretions and thus identification remains uncertain.

Hot-working *v.* cold-working

Archaeological associations are of little assistance in attribution of the hammers, nor in determining the metal species being worked. Only hammer No. 64 was found with metalworking residues (iron slag). The set hammers and the swage hammer (Nos 56-58) seem likely to have been used solely for iron-forging, whereas the other two large hammers (Nos 59 and 60) may have been for working iron or non-ferrous metals, though the former seems more likely. Thus, few large iron-forging hammers are known, and it may be that iron was generally worked with lighter hammers, such as No. 64. Other characteristic iron-forging tools such as flatters and large fullers (CoSIRA 1955, 12), which are fairly similar in form to set hammers, are not known from the Iron Age in Britain, though possible examples are known from the Continent (e.g. Darnay 1906, 423, no. 21; Pleiner 1980, fig. 11.6, 4 and 5).

A greater number of the hammers seem characteristic of cold-working techniques such as raising and sinking. Today, these techniques are more commonly associated with non-ferrous metalworking, but there seems no reason why they may not have been used in the Iron Age to cold-form iron plate (e.g. shield bosses).

Eyes and haftings

The eyes of the hand hammers are all elongated, generally rounded-rectangular or oval in plan, though a few are almost biconvex. It has long been recognised that the shape of the eyes of Iron Age hand hammers is their main distinguishing feature from those of Roman date, which invariably have circular eyes (Piggott 1953; Manning 1969, 79, nos A42-A61). Exceptions include a single hammer each from Carlingwark Lock, Kirkcudbrightshire (Piggott 1953, 37, C42, fig. 9; see also Manning 1981, 58), near ?Walling, Northumberland (Manning 1976, 24, no. 52, fig. 14), and Gestingthorpe, Essex (Manning in Draper 1985, 46, no. 152, fig. 20).

The two set hammers (Nos 56 and 57) have circular eyes, and this seems to be normal in Iron Age set hammers and single-faced hammers from the Continent, for example at Manching, Bavaria (Jacobi 1974, 270, nos 6, 7 and 8, Taf. 1) and Kappel, Kr. Saulgau, Germany (Fischer 1959, 33, no. 46, Taf. 15). In these examples, where the eye is off-set, it seems possible that the eyes were created around formers, perhaps in the manner suggested for the eyes of axe-heads (cf. Pleiner 1962, fig. 45).

Remains of wooden handles survive in at least eight hammers (Table 3:2), possibly also No. 70, and in No. 68 when originally discovered. In seven of these haftings there are one or more iron wedges. The woods where identified are all fine-grained from mature trees - species which should have provided suitable resiliency for percussion tools (cf. Salaman 1989).

Chronology

The earliest hammers are possibly Nos 62 and 71 from Fiskerton which may date from the fourth century BC. Others which are potentially early are Nos 60, 61 and 72. Nos 75 and 84 may possibly date from around the second century BC. Eighteen hammers have associations or contexts dating to the first century BC or early-mid first century AD; three others (Nos 56, 57, 59) may be of similar date. Of the remainder, five (Nos 66, 70, 76, 81, 83) are unstratified and without archaeological associations, but can most probably be assigned a pre-Roman date from the form of the eyes. Only two of these (Nos 66 and 76) are from a site with post-Roman activity (Ham Hill). Although it has been noted above that medieval hammers also often have elongated eyes, the metal structure of Nos 66 and 76 is more in keeping with Iron Age technology (cf. Tylecote and Gilmour 1986, 76).

The angled type of hammer occurs in pronounced form in Nos 64, 65 and 80, all from early or mid-first century AD contexts. The angle is much less marked in Nos 81 and 83 which are unstratified but possibly of the same date, and No. 82 from a first century BC burial. The pronounced angled profile is common on late Iron Age hammers from the Continent, for example at Manching, Bavaria (Jacobi 1974, 270, nos 1, 2 and 4, Taf. 1), Stradonice, Bohemia (Pič 1906, 84, pl. XXXV, 27 and 31, pl. XXXVI, 1, 2, 8 and 9), Celles, Cantal (Pagès-Allary *et al.* 1903, 396-7, no. 19, fig. 21), Kelheim, Bavaria (Herrmann 1973, Abb. 5, 7) and Lacoste, Bordeaux (Boudet 1984, pl. 141, 2). It is possible therefore, that the British angled examples are a result of Continental influence. Thus, the angled hammers (with elongated eyes) form a distinct group, the shape probably unrelated to function, and in pronounced form are known only from the first century AD in Britain. The type does not seem to occur in the Roman period in Britain (cf. Ohlhaver 1939, Abb. 14 for continental examples) though does reappear in early medieval contexts (also with elongated eyes), for example at Thetford (Goodall 1984, 77, no. 4, fig. 115), Coppergate, York (P.

Ottaway forthcoming), and elsewhere (Ohlhaver 1939; Goodall 1980).

The small copper alloy hammer alleged to be part of the Polden Hill hoard (Brailsford 1975, 232, no. 5, fig. 7, j), but of dubious association (cf. Harford 1803, and BM accession register 1846.3-22) has recently been analysed by Dr Paul Craddock (BMRL File no. 5638). It is made of brass (*c.* 20% zinc) which almost certainly excludes it as an Iron Age hammer; its lack of Roman and medieval parallels and similarity to modern jewellery hammers tends to suggest a rather recent date.

Metalworking associations

Hammer No. 64 was found with iron slag and ashes at the bottom of a ditch at Casterley Camp (Cunnington 1913, 103). No. 84 was found near ferrous and non-ferrous metal residues at Glastonbury, though need not have been associated with the debris. A rubbish pit at Oare yielded hammer No. 80 and also iron slag, together with a quantity of domestic debris (Cunnington 1909) including early and mid-first century AD imported pottery and mid-first century AD kiln debris (Swan 1975). Two hammers, Nos 58 and 84, have traces of haematite on their surface, suggesting that they had been left on a hearth; No. 84 also has traces of the burnt handle.

Other relevant associations

Five hammers are from burials: Nos 65, 67, 78, 79 and 82, of which Nos 67 and 78 occur with other metalworking tools, and also weapons. Eight hammers are from certain or probable hoards of metalwork: Nos 56, 57, 58, 59, 62, 63, 68 and 71, of which those from Waltham Abbey (No. 58) and Fiskerton (Nos 62 and 71) are very probably ritual in deposition.

Metallurgy

Fourteen of the hammers were examined by metallography; the results are summarised in Table 3:3. Four hammers (Nos 61, 63, 68, 72) had been examined previously for elemental composition by Ehrenreich (1985) but the metallographic results presented here differ from his conclusions concerning carbon content and heat treatment (cf. Ehrenreich 1985, 63).

Seven hammers were sampled at one face only, another seven were sampled at both faces, and of these, four were also sampled at the eye. The majority of the hammers were made of medium-carbon steels

(Table 3:3, types B and C) but exhibit the variation in carbon which may be expected in bloomery iron, sometimes with high-carbon regions juxtaposed with carbon-free zones. Ten had been quenched: the two possible raising hammers (Nos 61 and 62), the three possible sinking hammers (Nos 71, 72, and 73 rectangular face), two of the possible planishing hammers (No. 73 rounded face, and No. 76), three other cross pein hammers (No. 66 rectangular face, and Nos 67 and 68) and a 'general-purpose' hammer (No. 86). In three of the hammers, at least one of the quenched faces is well-burred, and this may be due to the uneven carbon distribution in the structures.

Three hammers (Nos 62, 68 and 71) had been selectively quenched at the faces whereas the eyes were left in the air-cooled condition. The weakest area of a hammer is potentially the eye (Weygers 1973, 58), and it therefore seems possible that some Iron Age metalworkers were aware of the advantage of maintaining a softer and tougher body

Table 3:3 Hammers: summary of metallography

No.	Faces examined	Air-cooled	Quenched	Annealed	Sample: Face(s)	[Eye]
61	1		C		S11	
62	2		B		S12/S13, S14	[S15]
63	1			C	S16	
66	2	A	B		S17/S18, S19	
67	1		C		S20	
68	2		B		S21, S22	[S23]
71	2		A		S24, S25	[S26]
72	1		C		S27	
73	2		B		S28, S29	
76	2		A		S30, S31	[S32]
77	2			C	S33, S34	
84	1	C			S35	
86	1		C		S36	
89	1	B			S37	

A Ferrite and/or low-carbon iron (below c. 0.3%C)

B Unevenly carburized: medium- and/or high-carbon steel, but with low-carbon soft areas

C Hardenable steel: medium- and/or high-carbon (over c. 0.3%C) to the hammers to prevent fracture. Another hammer, No. 76, had been quenched at the eye as well as at the faces, the microstructures suggesting simultaneous quenching of the whole hammerhead.

Hammer No. 66 had been treated differently at the two faces; the cross pein face was severely quenched whereas the rounded face was air-cooled. This suggests that hardened faces were not always desired. Two other hammers were air-cooled (Nos 84 and 89), and two were annealed (Nos 63 and 77), though in the latter two, prolonged (?accidental) heating on a hearth cannot be discounted. Of these four which had not be quench-hardened, Nos 84 and 89 may have been general-purpose hammers, but the two which had been 'annealed' were probably specialised hammers. Of particular note is No. 77, which is very similar in form to No. 76, and also to Nos 71-73, all of which had been quenched. It is possible that No. 76 had been intentionally softened by annealing, and, like No. 66 (rounded face), may have had some function for which a soft and tougher face was preferred. Both Nos 63 and 77 comprised medium- or high-carbon steel, which if they <u>had</u> been severely quenched, would have been very hard and also brittle.

None of the Iron Age hammers revealed evidence of deliberate tempering, though some had been slack-quenched - which effectively achieves a lower hardness but not necessarily any increase in toughness and strength. The most uniformly carburized and severely quenched hammer was No. 62, which had been quenched to over 800 HV at the cross pein.

3.7. <u>Chisels and sets</u>

Nos 90 - 117. Figs A13 - A15. Metallography S38 - S45.
Date category *A*: Nos 92, 96, 98, 105, 107, 109, 110, 113, 114, 116, 117. *B*: Nos 101, 102, 111, 112. *E*: Nos 90, 91, 93, 94, 95, 97, 99, 100, 103, 104, 106, 108, 115.

This Section comprises cutting tools for severing or marking metal, but excludes very small chisels and tools for removing or scoring metal (gravers, scrapers, and scribers), which are discussed in Section 3.10.

Tool marks on Iron Age metalwork attest the use of sharp cutting tools, presumably chisels, for example on iron off-cuts from Gussage All Saints (Chapter 5.2.1) and on copper alloy sheet scrap from Santon, Norfolk (Spratling 1966b). Other tools which may have had cutting functions in antiquity are shears, saws, and hardies. None of the surviving Iron Age shears and saws are likely to have been used on metalwork, and in any case these categories of tools were probably not employed for metalworking until the Roman period or later - in certain parts of Europe (Ohlhaver 1939; Ogden 1982, 43). Hardies are iron-smithing tools which are inserted into slots in anvils; the known anvils from Britain and the Continent are not furnished with slots until the Roman period (Section 3.4), and these slots are circular and inappropriate for anvil tools such as hardies (Manning 1969, 63-4). Thus, these types of tools are unlikely to have been used in the Iron Age, and no examples are known.

Functional differences between chisels and sets

Sets are iron-smithing tools which are generally stouter than chisels; they are either hafted or handled with rods, and struck with a sledge hammer (CoSIRA 1955, 10; Bealer 1969, 89). Chisels are usually more slender tools which are hand-held and struck with hammers or mallets. As their names indicates, hot sets and hot chisels are used to cut hot metal whereas cold chisels and cold sets are used on cold metal. Hot chisels and hot sets are therefore principally or always iron-forging tools, and are furnished with long handles to keep the hand away from the hot metal, or in the case of sets, also away from the sledge hammer. Modern examples of the tools discussed in this Section are shown in Figure 3:3.

Attribution of chisels and sets

Sets and chisels are not readily classified into specific function (Manning 1985, 8). Similar tools may have been used for working other materials, for example to carve stone (e.g. Blagg 1976 for Roman examples) or wood, or to serve as wedges for splitting these materials. Wood chisels often have flared cutting edges, and are struck with a mallet or applied with hand pressure (Manning 1985, 21-4). In the Iron Age they were commonly socketed (e.g. Sellwood 1984, 351, fig. 7.11, nos 2.44-2.46). Chisels may also have been used for quarrying, and these may be expected to be stouter tools with thick, strong tips. The large chisel from Lesser Garth, Glamorgan, of later Iron Age or Roman date (Savory 1966, 33-4, fig. 2, 4), may well be a quarrying tool.

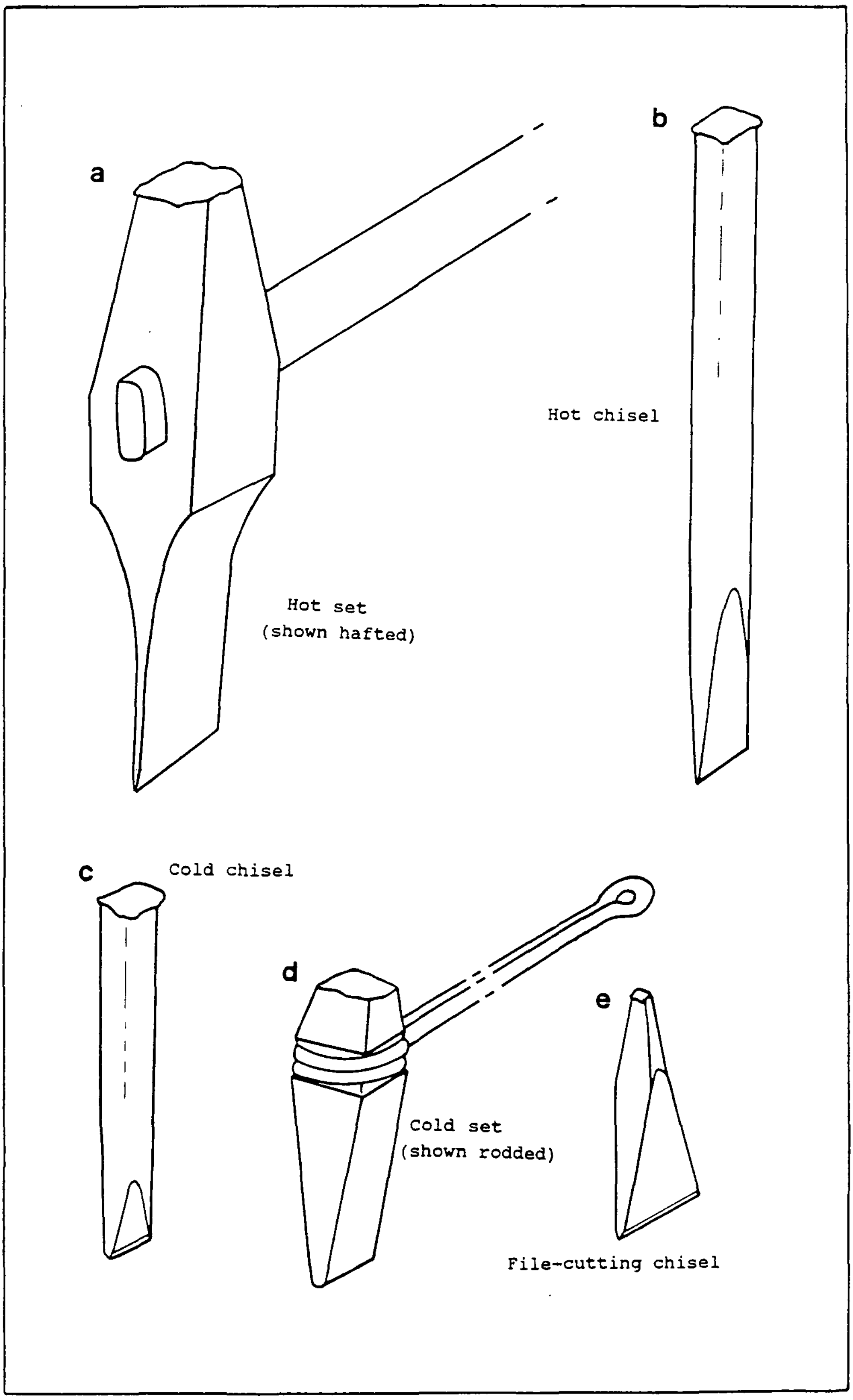


Figure 3:3 Modern chisels and sets: diagrams of principal types

The most useful characteristics for classification are according to the means of holding the tool and thus method of use, in conjunction with overall form. The cutting edge alone seldom assists division since a thin cutting edge may be usefully employed for cutting hot metal, soft non-ferrous sheet metal, or other soft material. Hot chisels probably require a length greater than about 150mm if grasped in the hand, though perhaps only a length of 120mm if held in the fingers and used for light work (e.g. to mark metal rather than to cut heavy bar).

The Iron Age tools which probably or very possibly had metal cutting functions are discussed below.

Hot sets

Hot sets are not unlike 'axe-hammers' but their main distinguishing feature is the long slender blade and the straight cutting edge. The similarity between these tools leads to uncertain identifications. For example, an axe-head from Hunsbury (Fell 1936, 65) is called a top fuller (a similar tool in form, but not function) by Ehrenreich (1985, 26, fig. 2.3). No. 90 is catalogued in this study as a probable hot set, though Manning considers it to be an axe-hammer (Manning 1985, 31, C1, pl. 13).

The slender tool, No. 108, with a perforation just below the head may be a variety of hot set for light work, or may equally have been used as a hot chisel.

Chisels

The probable hot chisels (Nos 91-105) have lengths upwards from 180mm, and their cutting edges are straight or barely flared. The slender chisel No. 105 was presumably for light working. Nos 106-108 may also have been used as hot chisels, though the first two may equally have been cold chisels, and No. 108 is discussed above as a possible hot set. The shorter stout chisels (Nos 109-112) were probably for cutting cold metal.

The cross-sections of the chisel stems range from square or rectangular to round, or a combination of forms. At the upper stem, a round cross-section seems common (Nos 99, 101-5, 107 and 109).

Most of these chisels are relatively narrow in the stems and tips and thus it seems unlikely that they were used for quarrying. These include the six unstratified tools from Hunsbury - a site where the local ironstone was probably quarried during the Iron Age (Knight 1984).

Cold sets

Nos 113-117 may be cold sets or cold chisels, though other purposes such as wedges cannot be discounted. No. 114 has a recess below the head which may have been for handling the tool with rods. Nos 113 and 116 were made of quench-hardened steel (Tylecote 1975, 5-6, no. 283; Ehrenreich 1985, 63, fig. 3.9), which gives additional support to their identification as a metalworking tools. Nevertheless, wedges (particularly those for splitting stone) may also have been hardened and therefore this criterion alone cannot be used for identification.

Possible file-cutting chisels

Gussage All Saints yielded the largest number of files known from an Iron Age site, six of which are from pits 209 and 437 (which contained great quantities of metalworking debris: Chapter 5.2.1). Nos 114 and 116 are also from these two pits, and it seems very likely therefore that these were metalworking tools, possibly cold sets, but conceivably file-cutting chisels. Recent examples of chisels for the hand-cutting of files are triangular in shape and have broad cutting edges (Figure 3:3e). The angle of the cutting edge, angle of impact, and the blow applied to the chisel determines the angle and size of the file cut (Fremont 1920, 99-103), discussed further in Section 3.8.

Other chisels

Nos 204-206 may be small chisels for intricate work (Section 3.10.3). Other possible metalworking chisels are listed in Table 3:4. Identification is uncertain owing to condition; some may have been punches or other tools, and thus a number appear also in Table 3:9.

Chronology

The probable dates for the archaeological contexts of the chisels and sets may be summarised as follows:

(1) 5th - 3rd centuries BC: Nos 96, ?112, 117.

(2) 3rd - 1st centuries BC: Nos 98, 109, 113, 114.

(3) 1st centuries BC and AD: Nos 93, 95, 102, 105, 115, 110, 116.

(4) 3rd/2nd century BC - mid-1st century AD: Nos 92, 99, 101, 107, 111.

(5) Unstratified: Nos 90, 97, 106 (all possibly post-Iron Age), and also Nos 91, 94, 100, 103, 104 and 108 (from Hunsbury).

Table 3:4. Other possible chisels (not catalogued)

Site	Tool	Source	Probable date
Croft Ambrey	?chisel blade	Stanford 1974, 174, fig. 82, 7	C1st BC
Danebury	3 chisels, wedges, or punches	Sellwood 1984, 370, fig. 7.24, nos 2.185, 2.186 and 2.187	300-100/50 BC
Danebury	?hot chisel head	B. Cunliffe forthcoming (no. 2.255)	300-100/50 BC
Gretton	chisel or punch	Jackson and Knight 1985, fig. 83.6	IA
Hod Hill	?hot chisel tip	Manning 1985, 23, B34, pl. 10	IA or C1st Roman
Hod Hill	4 chisels or punches	Manning 1985, 10, A23-A26, pl. 5	IA or C1st Roman
Hod Hill	cold chisel or punch	Durden collection BMP1892 9-1 1300	IA or C1st Roman
Hod Hill	?cold chisel tip	Durden collection BMP1892 9-1 1301	IA or C1st Roman
Hod Hill	cold set or wedge	Durden collection BMP1892 9-1 129?	IA or C1st Roman
Meare West	chisel or punch	Bulleid and Gray 1953, 239, I40	C2nd BC-C1st AD

Metalworking associations

The slender, probable hot chisel No. 105 was recovered from a dump of mixed metalworking debris at Weelsby Avenue. A hot chisel each from Glastonbury (No. 92), Meare Village East (No. 99) and Meare Village West (No. 111) were found close to iron slag though archaeological relationships for these tools cannot be determined.

Cold chisel No. 110 comes from a metalworking area at South Cadbury where it was found near scrap metal from sheet bronzeworking. Two of the possible cold sets or file-cutting chisels (Nos 114 and 116) were found with mixed metalworking debris at Gussage All Saints.

Other relevant associations

Chisel No. 107 comes from a hoard of ironwork which includes currency bars and an axe-head. Hot chisel No. 95 may be from a hoard of ironwork which includes other metalworking tools. Hot chisel No. 98 was recovered from a grain storage pit.

Metallurgy

Seven hot chisels, one cold chisel, and two cold sets have been examined by metallography, either by the writer (Appendix B) or by other workers (Tylecote 1975; Salter 1984; Ehrenreich 1985). The eight tools examined in this study had all been sampled and analysed for elemental composition by Ehrenreich (1985).

Four of the hot chisels (Nos 91, 94, 100, 108), all from Hunsbury, were made from medium- or high-carbon iron, and in addition, the latter three revealed possible evidence of surface carburization. The other hot chisels examined were made from iron containing low carbon (Nos 95 and 103), or very unevenly distributed carbon (No. 104). All these seven chisels had been air-cooled.

Cold chisel No. 109 was examined by Salter (1984, 435, Mf 13:C4, D185 and D186); the stem comprises very low-carbon iron, 121 HV, whereas the tip comprises medium-carbon steel, 272 HV. Two cold sets (Nos 113 and 116) were made of medium-carbon steel and are quenched and possibly tempered, though it is not certain if the tempering was deliberate (S39; Ehrenreich 1985, 63, 215, WD11a, fig. 3.9; Tylecote 1975, 5-6, no. 283).

Cutting tools require toughness in particular, and for cold work a high hardness is required to prevent damage to the tool (cf. Table 1:4). Although hot chisels are today normally quenched and tempered (CoSIRA 1955, 9), the relative ease with which iron can be hot-worked (p. 52) suggests that extreme hardness is not necessary for hot chisels. It is possible, therefore, that the Iron Age hot chisels had not been quenched because they were satisfactory as forged, or that it was preferable to have a rather softer and less brittle tool if the process of tempering was generally unknown.

3.8. Files

Nos 118 - 161. Figs A16 - A19. Metallography S46 - S59, S64 - S66. Date category *A*: Nos 121, 122, 123, 128, 130, 135, 139, 142 - 157, 160, 161. *B*: Nos 118, 120, 126, 129, 131, 133, 134, 137, 138, 158, 159. *D*: No. 141. *E*: Nos 119, 124, 125, 127, 132, 136, 140.

The use of files on various materials

Tool marks on Iron Age metalwork, apparently from the use of files, suggest that these tools were employed for a variety of purposes including enlarging open-work designs (Jope 1961a, no. 26, and p. 328; Jope in Cunliffe 1984b, 343, nos 1.25-1.27), reducing edges of components of composite objects to enable construction (Stead *et al.* 1980, 68), finishing (e.g. Watson 1949, 44), and possibly for decorative effects (Stead 1985a, 20). It seems likely that files were used principally for finishing and smoothing - purposes which do not necessarily leave tool marks, or at least not certain marks from the use of metal files. The well-finished appearance of certain types of Iron Age artifacts has been remarked upon by Spratling for southern British decorated metalwork (Spratling 1972, 253-4, 355), and by Jacobsthal for continental material (Jacobsthal 1944, 130-1). Other materials which may have been employed for finishing and smoothing metalwork include whetstones, sand slurries, and other natural materials, since these uses are known from ethnographic sources (Fremont 1920).

Classical sources indicate the early use of files on metals and on wood (Gaitzsch 1980, 47-8). Medieval, and ethnographic sources suggest that a much wider range of materials may be worked with files (e.g. Fremont 1920; Ohlhaver 1939). However, 'chatter' marks (MacGregor 1985, 56) on Iron Age bone artifacts (Penny 1975; Cunliffe 1984b, fig. 7.38) suggest that knives or other types of blades were used to fashion some bone implements. Nevertheless, during the Iron Age, it is possible that files may have been used to work (or at least to finish and smooth) artifacts made in bone, antler, wood, horn, and possibly other materials, as well as metals.

At least three bronze files of Hallstatt date are known from the Continent: from Hallstatt in Austria, Velem St. Vid in Hungary, and Bologna, Italy (Ohlhaver 1939, 71-2; Singer *et al*. 1954, 613, fig. 407). These were not necessarily metalworking tools of course, and it seems unlikely that they were, but they demonstrate that the file was used in Europe well before the known occurrences of iron files from Britain and the Continent.

<u>Attribution of the Iron Age ferrous files</u>

All of the known Iron Age files from Britain have parallel single ridges (single-cut), and are transverse cut (Figure 3:4a) except for three which also have a few diagonal ridges (Nos 134, 158, 159). The ridges (or cuts), which form the teeth, are invariably inclined or raked forwards to the tip of the blade (the point).

According to Manning, finely cut files were always metalworker's tools, whereas more coarsely cut files were used for woodworking and other crafts (Manning 1985, 11, 28; also Salter 1984, 435). Furthermore, the files with cranked tangs which are known from Roman and later periods are thought to have been used principally for carpentry, and in farriery to file horses' hooves (Manning 1985, 28). However,

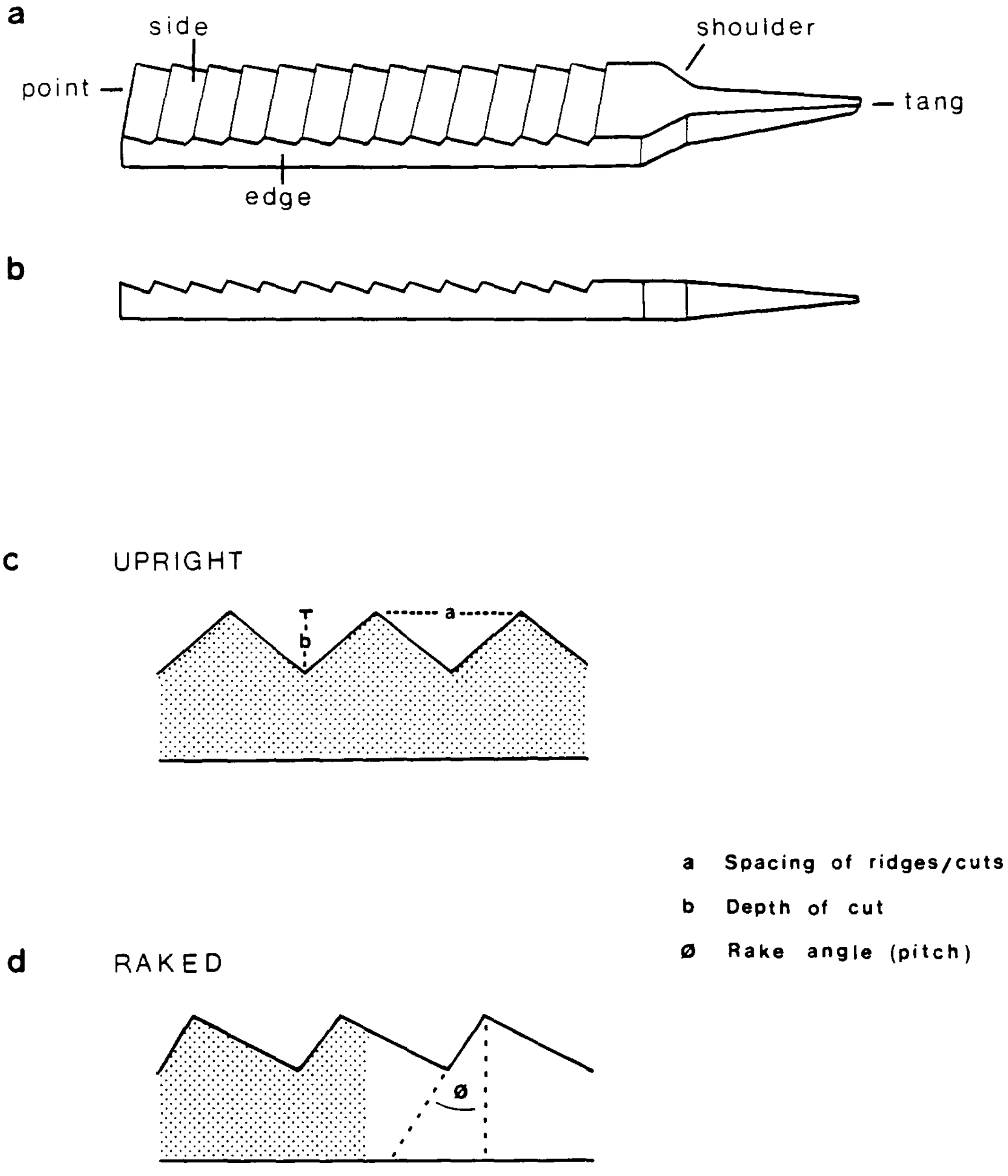


Figure 3:4 Diagram of a tranverse-cut file: nomenclature and form of cuts

these attributes of files (fine spacing and cranked tangs) are now known to occur together, an apparent contradiction if form evolves from function.

Archaeological associations do not always assist in determining the type of material worked. For example, 'hoards' of ironwork which contain metalworking tools often also include tools for working other materials (cf. Manning 1972). Some files from metalworking areas and dumps of metalworking debris may conceivably have been employed for making wax-modelling implements or handles of tools. However, a number of the files have non-ferrous metal inclusions in their cuts (see below p. 140-1) suggesting that they had been employed for metal-working - at least at some stage of their lives.

Properties which may be useful in attribution are size, cross-section, number of cut faces, nature of the teeth, metal hardness, and type of handle (i.e. method of use). In order to evaluate the known Iron Age files in terms of a possible metalworking function, their working characteristics are examined below. The technical aspects given below are largely derived from the historical and technical study of files by Fremont (1920), and relate to single-cut files of similar form to those of the Iron Age.

(1) The size of a file and its cross-section are normally selected according to the form of the workpiece. A broad file, matching the flatness or curvature of the workpiece, removes material more evenly than one of smaller surface area, and reduces the chance of embedding unwanted tool marks. On the other hand, a rounded file, when used on a flat surface, enables a greater amount of localised work (Fremont 1920).

(2) The number of cut faces on an Iron Age file may have depended on technical difficulties in making the files, though the number of multiple-faced files known suggests that this was not the case. Another important element is the occasional need for an uncut 'safe' edge (BS498: 1960, 6) to enable the filing of a single surface of a complex construction without marking adjacent ones.

(3) The spacing and depths of the cuts relate to the type of material being worked, and the nature of the work (Fremont 1920; Simons 1947, 107). A file of extreme fineness is likely to clog very rapidly if used on soft or fibrous materials. A coarse-cut file produces larger filings than a fine-cut file, requiring a greater

expenditure of energy, and more likely to be damaged by use on hard materials (Fremont 1920, 99-103). Spacing and depth of cut, and the size of filings, effect the amount of work which can be performed before the file requires to be cleaned.

A coarse-cut file is normally selected for the removal of substantial quantities of material whereas a finer-cut file is used for smoothing.

(4) Raked teeth (Figure 3:4, b and d) are more efficient at cutting than are upright teeth (Figure 3:4c); sharpness is a less important factor (Simons 1947, 102).

(5) Since files function by a cutting action, the hardness of the file requires to be proportionately higher than the material being worked (Chapter 1.8).

(6) A cranked tang enables clearance over the workpiece, but less direct force may be applied.

(1), (2), and (4) above relate primarily to the scale, form, or efficiency of working any individual workpiece, whereas (3), (5), and (6) probably depend principally on the nature and hardness of the material being worked. The main properties which may assist in determining function may therefore be:

A. Spacing and depth of cuts

B. Type of handle

C. Hardness.

The occurrence of the Iron Age files under these three properties is examined below.

A. Spacing and depth of cuts

The frequency of the Iron Age files are shown in Figure 3:5a according to the degree of spacing of the teeth in those which can be measured with any accuracy. The files fall into four groups, which may be described in the following relative terms of spacing:

(1) Coarse-cut, with less than 6 cuts per cm

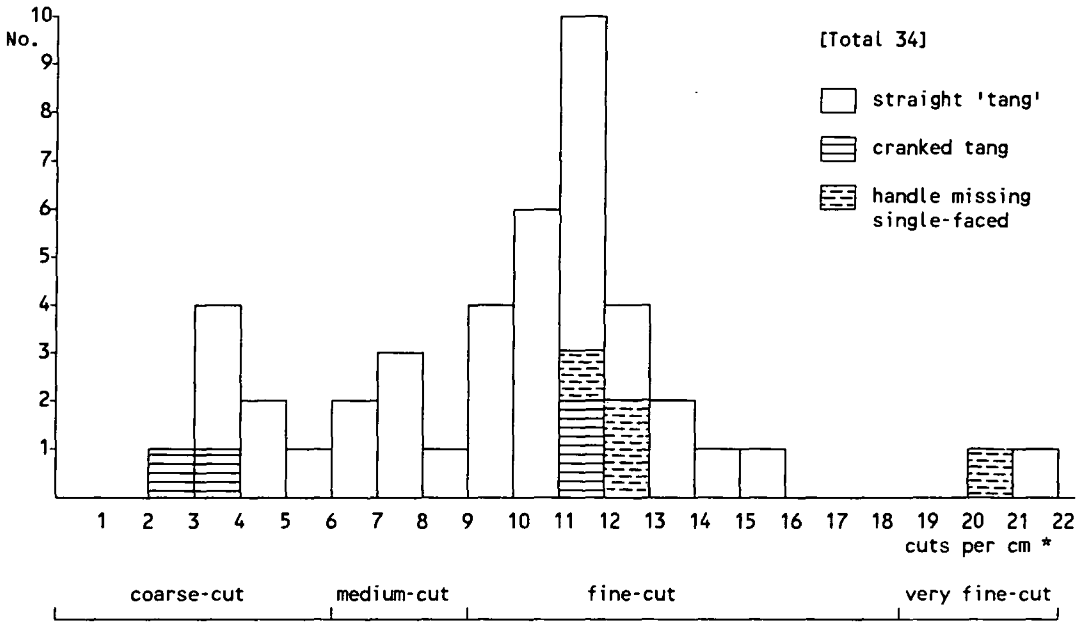
(2) Medium-cut, with about 6 to 9 cuts per cm

(3) Fine-cut, with 9 or more cuts per cm

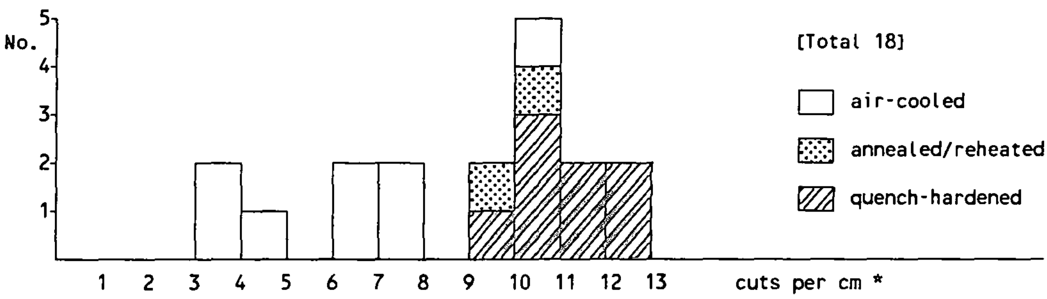
(4) Very fine-cut, with 20 or more cuts per cm.

The coarse-cut files from the Iron Age all have cuts which are 1mm or more in depth (Table 3:5) whereas the others have much shallower cuts.

a. All files (which can be measured)



b. Files examined by metallography



* Typical spacing where there is a range
Sources: Appendices A and B; Table 3:5; Tylecote 1975, no. 822; Salter 1984, 435, 2.54 and 2.55

Figure 3:5. Frequency of files according to spacing of cuts

	Site	Cross-section	Cuts/cm	Cut depth mm	Source
STRAIGHT TANG					
a.	Danebury		3 - 3.5	1.0	Sellwood 1984, 354, 2.54, fig. 7.12
b.	Glastonbury?		3.5 - 5.5	1.0	Unpublished (bag labelled ?GLV)
c.	Hod Hill		3 - 4	-	Brailsford 1962, 14, G35, fig. 13
d.	Meare West		4	1.5	Gray and Bulleid 1953, 247, Md XXII
e.	Rudston		5.5	1.5	Publication forthcoming (Gr. 141)
CRANKED TANG					
f.	Fiskerton		11	0.4	Publication forthcoming (SF298)
g.	Fiskerton		3 - 4	1.2	Publication forthcoming (SF364)
h.	Hod Hill		2.5	-	Brailsford 1962, 14, G36, fig. 13
i.	Twyn-y-Gaer		11 - 12	0.4	Publication forthcoming (5)
TANG MISSING					
j.	Bredon Hill		3 - 3.5	1.5	Hencken 1938, 83, no. 10, fig. 10

Table 3:5 Iron Age coarse-cut files and files with cranked tangs

B. <u>Type of handle</u>

The majority of known Iron Age files have straight tangs. Four cranked tanged files are known: two from Fiskerton, and one each from Hod Hill (which may post-date the Roman conquest) and Twyn-y-gaer (Table 3:5, f-i). Straight-tanged files are also rare on the Continent; the known examples are one each from Heidetränk in Germany (Müller-Karpe and Müller-Karpe 1977, 57, Abb. 6, 3), Celles, Cantal (Pagès-Allary *et al.* 1903, 393, fig. 10), and Stradonice, Bohemia (Pič 1906, 86, fig. 10).

C. <u>Hardness</u>

From the hardness of a file it may be possible to predict if it was suitable only for use on soft materials. A soft (unhardened) file may be adequate to work materials such as wood, horn, or soft metals (e.g. tin, lead, and annealed iron, copper and low alloys), though of course a hardened file could also be used to work these materials.

Figure 3:5b shows the incidence of quench-hardening to spacing irrespective of degree of carburization and hardness achieved. This figure ignores possible hardening by carburization alone, or the use of phosphoric work-hardened iron.

According to these three properties (A-C above), the 54 known Iron Age files (Nos 118-161, and Table 3:5) may be divided as follows:

(1) Spacing: 8 coarse-cut, 6 medium-cut, 38 fine-cut, 2 very fine-cut.
(2) Handle: in all but 11 of the files, sufficient evidence of the form of the tang or handle survives to enable the means of hafting to be determined; 2 coarse-cut files and 2 fine-cut files have cranked tangs, whereas 5 coarse-cut, 5 medium-cut, and 29 fine-cut files have straight tangs or handles. In addition, a further 3 fragmentary multi-faced fine files presumably had straight tangs.
(3) Hardness: to date, 8 of 11 fine-cut files (all straight-tanged) have been shown to have been hardened by quenching (Figure 3:5b).

Correlations occur only in fine spacing and heat treatment. In the absence of evidence of heat treatment, the coarse-cut files seem to fall into a relatively discrete group. For the technical reasons indicated earlier, they are less likely to have been used for metal-working though this need not exclude them having been used on metals, either to file very soft metals, or conceivably to create metallic filings for soldering, medical, or other purposes (cf. Dioscorides *De materia medica* V, 91; Pliny *Natural History* IX, 33.30, 34.26, 34.49; Vitruvius *Architecture* VII, 11.1). Medieval and later sources record large coarse-cut files used by pewterers, copper-workers, saw-makers and cutlers, as well as horn-workers and woodworkers (Fremont 1920, 15, figs 30, 97 and 101; Roberts n.d., figs 1-3).

Correlations do not occur between spacing and type of handle. Cranked-tanged files are commonly termed 'floats', a derivation possibly from plasterer's tools for levelling and smoothing (Roberts n.d., 12). Historical sources indicate that cranked-tanged files were used only for levelling, smoothing, and special purposes, and furthermore, only to work soft materials such as wood, horn, bone, and leather (Fremont 1920, 14; Roberts n.d.). These files appear to range from coarse to fine in spacing.

On the basis of the historical evidence, and because cranked tangs enable less force to be applied, it is proposed that the Iron Age examples are unlikely to have been metalworker's tools. Providing this attribution is correct, then of special note are the anomalies from Fiskerton and Twyn-y-Gaer (Table 3:5, f and i), both with 11 cuts per cm, which suggests that the fineness of cuts at this range cannot be used as the sole criterion to determine metalworking files (cf. Manning 1985, 11). Both of these files are narrow and have shallow cuts. Possibly they were used for smoothing, for example mortises, or slots in other materials (e.g. antler linch pins), rather than actually removing substantial surface layers of material.

Thus, the tools which are catalogued as tools with probable or possible metalworking function are those of medium and finer cut, which have (or probably had) straight tangs. The six medium-cut files are included (Nos 119, 122, 123, 124, 127 and 128), and while it is likely that some of these may have been intended for use principally on non-metals, the possibility exists that they may have been metalworking tools. One of these, No. 122, has two copper-based inclusions embedded in the cuts (see below p. 140-1).

The forty-four catalogued files are divided into flat files (Nos 118-140, 154-159) and rounded files (Nos 141-153), of which five of the latter have both flat and convex faces (Nos 145, 147, 148, 150 and 151). The principal attributes files are shown in Table 3:6.

No.	Cross-section	No. of faces	'Blade' * length mm	Cut faces # max. width mm	Cuts/cm typical	(range)	Raked teeth
FLAT FACED							
118	rectangular	1	195+	19	9.5		-
119	square	1	132	7.5	6.5		yes
120	trapezoidal	1	146	9	10.5-13		yes
121	rectangular	1	-	-	11		yes
122	<rectangular	1	-	8.5	7-8		yes
123	plano-convex	1	56+	8	7-8		yes
124	plano-convex	1	-	9.5	6.5-7.5		yes
125	rectangular	1	106+	8	-		-
126	rectangular	2	102	7.5	10-13	(7-15)	yes
127	square	2?	-	-	7		-
128	square	3	-	-	7-9		yes
129	<square	4	-	10.5	11	(10.5-11.5)	no?
130	rectangular	4	-	9	7-10.5		yes
131	square	4	93	8	8-11		yes
132	rectangular	4	73+	9	10-12.5	(6-12.5)	yes
133	rectangular	4	-	7.5	10	(9-12)	yes
134	rectangular	4	-	-	10-13		yes
135	triangular	2	-	-		(8-?33)	-
136	square	1	-	-	-		-
138	rectangular	-	-	9	-		-
139	rectangular	-	-	9	-		-
140	rectangular	-	-	12	-		-
154	trapezoidal	1	-	-	12		yes
155	trapezoidal	1	-	-	14-17		yes
156	plano-convex	1	-	7	20.5		yes
157	square	1	-	3.5	20-22		yes?
158	rectangular	4	-	8.5	8-12.5		no
159	rectangular	4	-	8	10		no
ROUNDED FACED							
141	>square	1	187	8.5	10-12.5		yes
142	>rectangular	2	-	9	8.5-10		yes
143	oval/round	1	126	8	9-10		yes
144	>rectangular	1	-	7	12-15		yes
146	>trapezoidal	1	39	6	14	(14.5)	yes
152	plano-convex	1	-	-	12-14		yes
153	round	all	-	4.5	11		no?
FLAT + ROUNDED FACED							
145	>rectangular	2	88+	4.5	11	(10-14)	yes
147	plano-convex	2	169	10	9-12		yes
148	plano-convex	2	104+	11	10-12		yes
150	plano-convex	2	-	10	8-11		yes
151	>square/round	1	63	4	12-14		yes
FORM NOT KNOWN							
137	rectangular	-	164	9	-		-
149	plano-convex	-	142	10	-		-
160	?	-	-	-	-		-
161	?	-	-	28	-		-

* Cut length of blade, given only if c. complete; + indicates slight loss

Given only if representative of likely maximum dimension

Table 3:6 Medium-cut and fine-cut files: principal attributes

Flat files

1. Single-faced: rectangular, square, or trapezoidal in cross-section, Nos 118-122, ?125, 136, 154, 155 and 157
2. Single-faced: plano-convex section, cut on the flat side, Nos 123, 124 and 156
3. Two-faced: rectangular cross-section, No. 126 and possibly No. 125, and No. 127 cut on two adjacent edges (though this may well have been a three- or four-faced file)
4. Three-faced: square section, No. 128, with one plain 'safe' edge
5. Four-faced: square or broad rectangular cross-section, Nos 129-134, 158 and 159
6. Knife file: No. 135
7. Possible files: no visible (or surviving) cuts, rectangular or square in section Nos 137-140, and plano-convex section No. 149.

The files with cut-away sides (trapezoidal section) or plain convex sides may have been made in this way to provide 'safe' edges. Those which are plano-convex in section, and cut only on the flat side, may otherwise have been prepared as blanks intended for cutting on both faces - but only one side was cut. Other possibilities are wear, or recutting (after wear) on the flat side only (cf. No. 147).

The fragments of files Nos 154 and 155 are of similar section and are from probable contemporary layers in pit 209 at Gussage All Saints (Chapter 5.2.1). They may therefore have been part of the same file.

The fragmentary knife file, No. 135, has few teeth surviving, though sufficient to indicate that it is most probably correctly attributed. Knife files occur in late Iron Age contexts on the Continent, for example at Celles, Cantal (Reinach 1917, 284, fig. 283, 50153), and in a first century BC context at the Magdalensberg, Austria (Schaaber 1963, 185-7, Taf. XXVI).

Rounded files

1. Single-faced: rounded-rectangular or trapezoidal in cross-section, and approximately regular in curvature, Nos 141, 144 and 146
2. Single-faced: flat or barely rounded in section near the tang becoming circular near the point, Nos 143 and 151
3. Two-faced: rectangular cross-section cut on the two opposing sides, Nos 142 and 145
4. Half-round: cut on the convex side only, No. 152, and ?No. 149

5. Half-round: cut on both flat and convex sides, Nos 147, 148 and 150
6. Wholly round: No 153 (?).

There is considerable variety of curvatures in these files, and in some the cross-section alters along the length, notably in Nos 143 and 151.

The five fragments of small files from Gussage All Saints (flat: Nos 154, 155, 156; rounded: Nos 152, 153) which come from probable contemporary layers, or at least were deposited within a short time of each other, suggest that the metalworkers at Gussage All Saints had available a wide range to suit their needs. The five files from Weelsby Avenue, which also occur in a wide range (flat: Nos 121, 122, 157; rounded: Nos 144, 151), were likely to have been deposited within a decade.

Handles and tangs

Twenty-five of the catalogued files have (straight) tapering, rectangular or square sectioned tangs, another five have broad 'tangs', three and possibly four (Nos 129, 158, 159, ?127) seem to have been held by other methods, and in the remainder the tang or handle does not survive. Traces of wooden handles survive on the tangs of Nos 118, 126 and 131.

In the majority of the files, the 'tang' merges with the blade and in some (e.g. Nos 132, 133, 146) the cuts extend partly down the tapered portion of the tang. In two files, Nos 142 and 145, both from Fiskerton, the tang-blade junction is clearly demarcated by shoulders.

Only one file, No. 118, has a ferrule. Ferruled tangs are known on the Continent, for example at La Tène (Vouga 1923, pl. XLIV, 21), Celles, Cantal (Pagès-Allary 1903, 393, nos 7 and 8, figs 10 and 11), and Chotín, Slovakia (Ratimorská 1975, 87, Taf. 5, no. 9).

One file, No. 129, seems to have an iron handle integral with the blade. This file is unusual also in having what appears to be a discontinuous copper alloy 'rod' or an alignment of solidified copper alloy droplets within the structure. Presumably the copper alloy was accidentally incorporated during the forging of the blank.

Two short files, Nos 158 and 159, both from Meare Village West, taper at both ends but do not seem to have had tangs. Files with tapered uncut portions at both ends are known from the Continent, for example at Lacoste, Bordeaux (Boudet 1984, pl. 141, nos 7 and 9), and the early bronze file from Hallstatt, Austria (Singer *et al*. 1954, fig. 407). Possibly files such as these were intended to be handled from either end, in which case their teeth were presumably not raked. This seems to be the case with files Nos 158 and 159.

The teeth

The commonest spacing of the cuts in the files is 10-12 cuts per cm (Fig. 3:5a), with sixteen (61%) of the measurable catalogued files (or 47% including the coarse-cut files) lying in this range. As mentioned earlier, the ridges are invariably inclined forwards, and some have a negative rake of a few degrees (Fig. 3:4d). This form of tooth is known to be very efficient at cutting (Simons 1947, 102).

Nos 158 and 159, mentioned above as possible unhafted files, have diagonal cuts as well as transverse cuts. It is possible that these may have been trial pieces, or may have been devised for a special purpose. Another file, No. 134, has just a few diagonal cuts although the majority are transverse.

The very small files, Nos 151-157, and those in which the cross-section alters (especially Nos 142 and 151), were presumably for finishing intricate or small items. Nos 156 and 157 are extremely finely cut (20-22 cuts per cm). The knife file No. 135 seems to be very finely-cut in some regions, though condition makes this uncertain. It is worth noting that a file from Steinsburg, Germany, reputedly has 40 cuts per cm (Spehr 1971, 500).

Files and fragments of files may be fairly readily determined by X-radiography providing the teeth are not too worn or corroded, for example in Plate IVb (accretions *in situ*). The three files in Plate IVa are severely corroded; none was identifiable before removal of at least some of the thick accretions - though this degree of corrosion is unusual (all but No. 157 shown in Pate V, a and b, were identified from their X-radiographs). Files are the largest group of tools catalogued in this study, one reason for which may be that they are readily recognised in fragmentary condition since their working surface extends the length of the 'blade'.

Tool marks

Striations on metalwork are not uncommonly reported, but some of these were possibly the result of using abrasive materials for finishing and smoothing. Single-cut files function by shaving away surface layers of the material being worked, unlike modern cross-cut files (Fremont

1920). The tool marks which may be expected from an evenly-cut and undamaged single-cut file should therefore be of low profile and possibly similar to those produced by a knife drawn across a material (such as during whittling). This has been demonstrated by the writer on a variety of different materials using simulated copies of Iron Age files. Since the devised files were not hardened, they could only be tried on soft metals, but no difficulty was experienced using a wrought iron file on annealed copper. It is worth noting that a damaged file, namely one with nicks out of the teeth, produces raised striations. Conversely, a dirty file with raised particles lodged in the teeth produces grooves in a workpiece.

Manufacture

The making of files during the Iron Age may have been technically very difficult, and perhaps involved the use of special tools. Possible methods of manufacture are therefore discussed below.

It seems reasonable to assume that the files were made by forging a blank to the required size and cross-section, then cutting the teeth, and finally conducting any heat-treatments.

The teeth of coarse- and medium-cut files may have been made by cutting with a hot set (cf. Jacobi 1974, Abb. 58, 3). Another possibility is that they were created or finished by filing using a second file, though this would require one of triangular or wedge section in order to create a rake. A very well-preserved coarse-cut file (or float) from Fiskerton (Table 3:5, g) has transverse grooves within the cuts suggesting that it was at least finished by filing or scraping. It may be relevant that Theophilus (twelfth century AD) notes that files are cut with a double-ended 'hammer', a chisel, or with a small knife (Hawthorne and Smith 1979, 93-4). Other medieval sources depict the use of a (?chisel-edged) hammer on cold metal (Ohlhaver 1939, fig. 55), or chisels struck with a hammer (Ohlhaver 1939, figs 56 and 57).

It may be that the Iron Age files, or at least the finer-cut files, were normally cold cut with a chisel, and possibly in the same manner that hand-cut files were produced up to the earlier part of the present century (Rees 1819; Fremont 1920, 104-5; Simons 1947, 28-9). This method involved embedding the cold blank in lead for support, and striking the blank repeatedly, from the point to the tang. A broad short chisel (Fig. 3:3e) was used in conjunction with a specially angled hammer (Fremont 1920, figs 145-147). No metal is removed during this process; the metal is forced up into ridges by displacement while the grooves are simultaneously created. The spacing and the depth of cuts depends on the force applied, whereas the rake was created by a combination of the angle of the chisel edge and the angle of application.

This method of making files, however, normally produces teeth which are raised above the level of the blank. It is noticeable on the better preserved Iron Age files (e.g. Nos 122, 124, 145, and Table 3:5, g) that the ridges (teeth) are lower than the level of the tang, and therefore, presumably, also below the level of the original blank (e.g. Plate IVb). If Iron Age files were cold cut with chisels, this tends to suggest that the technique was not identical to recent hand-cutting methods. Nevertheless, since many of the Iron Age files are cut on more than one face, and the majority are very regular in spacing and depth, this does suggest that there were no difficulties in their manufacture. As discussed earlier (Section 3.7), several short chisels (or cold sets, or wedges) are known from the Iron Age, two of which (Nos 114 and 116) may conceivably have been for cutting files.

The making of rounded files may have presented problems. A hollow chisel does not produce an even depth of cut since pressure cannot be exerted equally around the curvature (J. Nicholson pers. comm.). The cuts in No. 146 are deeper at the centre compared with the edges, which suggests that this file may have been chisel-cut. However, No. 146 is only slightly rounded; the half-round and round files could not have been created with single chisel strokes.

The hardening of files may also have given difficulties (cf. Rees 1819). Files may have been surface-carburized, though evidence of this has not been found in those examined by metallography, or due to corrosion (or wear) has not survived. A number were quench-hardened (discussed below), though technically this can present problems such as bending, particularly if a file is unevenly carburized or half-round in cross-section (Chapter 4.4.4).

Chronology

The probable dates for the archaeological contexts of the files may be summarised as follows:

(1) ?4th century BC: Nos 128, 135, 142, 145. Potentially early Nos 123, 138, 149.

(2) 3rd - 1st centuries BC: No. 143.

(3) 1st century BC: Nos 121, 122, 144, 151, 152, 153, 154, 155, 156, 157.
(4) 1st centuries BC/AD: Nos 126, 137, 139, 141.
(5) mid-1st century AD: Nos 125, 131, 136.
(6) 3rd century BC to mid-1st century AD: Nos 134, 148, 150, 158, 159.
(7) 2nd century BC to mid-1st century AD: Nos. 118, 120, 129, 130, 133, 146, 147, 160, 161.
(8) unstratified or without clear relationships: Nos 119, 124, 127, 132, 140. File No. 124 may be residual from Iron Age activity.

Of the files listed under (6) and (7) above (those from Glastonbury, Meare Village East, and Meare Village West), only Nos 120, 133, 146, 147, 148, 150 and 160 were found within, or under, clay 'mounds'; a date later than the first century AD is just conceivable, though unlikely, for the others.

<u>Metalworking associations</u>

Twenty-two files (50%) have potential metalworking connections. The largest assemblage of files is from Gussage All Saints. Five fragmentary files (Nos 152-156) are from the metalworking deposits from pit 209, though two of these (Nos 154 and 155) may be fragments of the same file. A further two (complete) files (Nos 126 and 143), and a third probable file (No. 137) are from other features at Gussage All Saints, of which No. 143 comes from a metalworking deposit. Metalworking dumps at Weelsby Avenue yielded five files (Nos 121, 122, 144, 151, 157). These two sites produced the smallest and finest-cut files known from the Iron Age, and in a wide range of cross-sections. At both sites bronze-founding seems to have been the major metalworking activity, and it is possible that these files may have been used to finish castings, as well as wrought products.

The seven files from Glastonbury (Nos 118, 129, 130, 133, 146, 147, 161) and five from Meare Village West (Nos 134, 148, 150, 158, 159) were all found close to metalworking debris, but archaeological associations cannot be established with any certainty. Nos 133, 146 and 147 from Glastonbury, have traces of haematite on their surfaces suggesting that they had been used near hearths. Nos 120 and 160 from Meare Village East are both from mounds which also yielded an anvil but little or no metalworking debris.

Other relevant associations

File No. 136 is from a probable metalworker's hoard from Santon (Norfolk) which contained scrap metal and other metalworking tools. Five files are from possible ritual deposits which contained other metalworking tools: Nos 128, 135, 142 and 145 from Fiskerton, and No. 141 from Waltham Abbey. File No. 131 is from a burial (Whitcombe) which also contained a hammer (No. 67).

Metallography

Nineteen files have been examined by metallography: sixteen during the course of this study including No. 119 examined by Ehrenreich for elemental composition (Ehrenreich 1985, 214, HYN68a). Three files have been investigated by other workers (Tylecote 1975; Salter 1984). The results are summarised in Table 3:7, except for No. 135 (S46) which gave inconclusive results.

The files studied by the writer comprise ten fine-cut files (plus No. 135, excluded), three medium-cut files, and two coarse-cut files. The majority were made from low- or medium-carbon iron, and in none is there evidence of surface-carburization. Seven of the fine-cut files were quenched, whereas all the medium-cut and coarse-cut files examined were air-cooled. Two of the fine-cut files had been thoroughly annealed, either intentionally or perhaps accidentally during prolonged use near a hearth. Only four files were of uniform carbon content, and of these, only two had been quenched. The other files were heterogeneous in carbon composition and hence uneven in microstructure and hardness - which would not have made efficient cutting edges. The file which revealed the most uniform structure was No. 148, which had a hardness range of 467-642 HV 0.5.

A fine-cut file from Gussage All Saints (No. 143) was examined by Tylecote and found to be unevenly carburized (comprising ferrite, pearlite and martensite) and quenched to a hardness of 358 HV 5 (Tylecote 1975, 6-7, no. 822; Spratling *et al.* 1980, 284-5, no. 822). Two files from Danebury have been examined by Salter (1984, 435, nos 2.54 and 2.55, Mf 13:C4, table 122, D172 and D133). A medium-cut file (No. 123) comprises very low-carbon iron and is of low hardness (141 HV). The other, a coarse-cut file (Table 3:5, a), comprises 0.3-0.4%C, hardness 225 HV. Neither file was apparently quenched (or they may have been reheated). Thus, these three files agree well with the

Table 3:7 Iron Age files: summary of metallography

No.	Air-cooled	Quenched	Annealed	Source
Fine-cut				
120		B		S48
126		B		S51
130		A		S52
132		A		S53
133		B		S54
142			B	S55
143		B		Tylecote 1975, 6-7, no. 822
147		A		S56
148		B		S57
150	B			S58
159			C	S59
Medium-cut				
119	C			S47
122	A			S49
123	A			Salter 1984, 435, no. 2.55, Mf13:C4, D133
124	A			S50
Coarse-cut				
Table 3:5, a	C			Salter 1984, 435, no. 2.54, Mf13:C4, D172
Table 3:5, d	C			S66
Table 3:5, g	B			S65

A Ferrite and/or low-carbon iron (below c. 0.3%C)
B Unevenly carburized: medium- and/or high-carbon steel, but with low-carbon soft areas
C Hardenable steel: medium- and/or high-carbon (over c. 0.3%C)

findings in Appendix B, namely that fine-cut files were frequently quench-hardened, but medium- and coarse-cut files have not yet been found to be quenched (Fig. 3:5b).

Modern files are sometimes surface-carburized in order to maintain a soft and tough core, and they are quench-hardened to around 900 HV but not normally tempered (Carr 1969, 16, 20). The Iron Age files were closely examined for traces of surface carburization; none was found though corrosion or wear may have obliterated the evidence.

Analysis of metallic inclusions

Seven files have non-ferrous metal inclusions in their cuts. Nos 142 and 145 each have twenty or more well-embedded inclusions. Nos 122, 126, 144, 152 and 156 each have a single or a few inclusions. Although the possibility exists that the metal particles from the latter five files were derived from their burial environment, those in Nos 126, 144 and 156 are well-embedded and therefore, like Nos 142 and 145, are likely to have derived from the use of the files on metal.

Analysis of inclusions in two files was undertaken, firstly to confirm their metallic nature, and secondly to investigate their composition. Samples, obtained with a scalpel, were mounted directly onto stubs, carbon coated, and analysed by scanning electron microscopy with X-ray analytical facility (SEM-EDXA). The results are shown in Table 3:8 and Figure 3:6. File No. 145 was too fragile to permit sampling, and was mounted whole (uncoated) in the SEM chamber, but excessive electron discharge did not enable analysis. The analyses were carried out, and interpreted by, Paul Wilthew (AML), Ted Heath (University of Southampton), and David Moore (UMIST, Manchester).

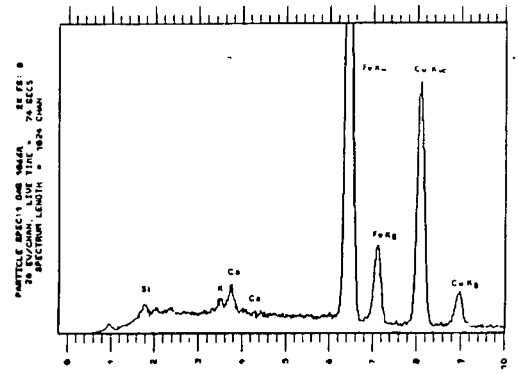
The results can be treated only semi-quantitatively, as an approximation of the metal composition on which the files were used. Two of the inclusions from No. 142 were later mounted in resin, polished and etched, and hardness tested. Both revealed very strained grains but no microstructure was discernible. The hardness of sample C was 151 HV 0.05 (range 146-154); sample D was 158 HV 0.05 (range 132-172). Thus, both inclusions were in the soft (as-cast or annealed) condition.

Table 3:8 Analysis of inclusions in file cuts

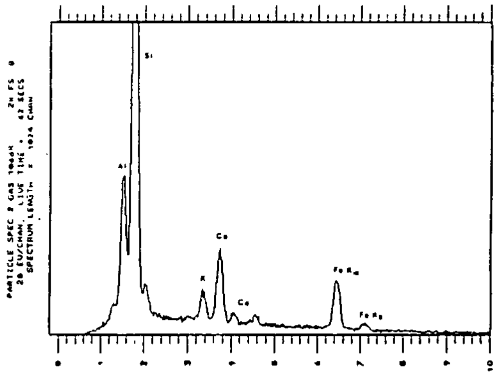
Sample	File	Colour	SEM-EDXA	Comments
A	142	yellow/pink	Cu Sn (tr Pb)	Fig. 3:6
B	142	yellow/pink	Cu Sn (tr Pb)	Fig. 3:6
C	142	yellow	Cu Sn	Cu : Sn = 81.1 : 18.8* Hardness 151 HV 0.05
D	142	yellow/pink	Cu Sn	Cu : Sn = 80.8 : 19.2* Hardness 158 HV 0.05
E	142	white	Pb	
F	142	white	Fe	?Residual iron structure
G	126	pink	Cu	Fig. 3:6
H	126	white	Fe	Fig. 3:6. ?Residual iron structure

* adjusted wt% with respect to major elements (ignoring obvious contaminants from burial)

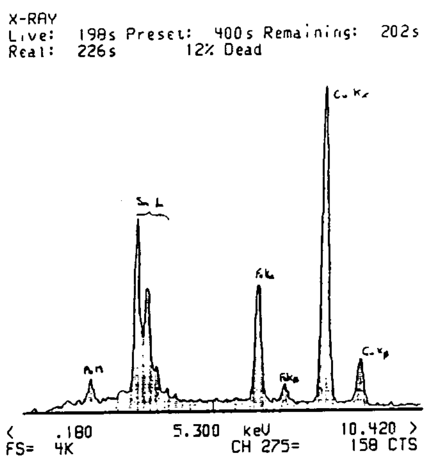
Sample A



Sample B



Sample G



Sample H

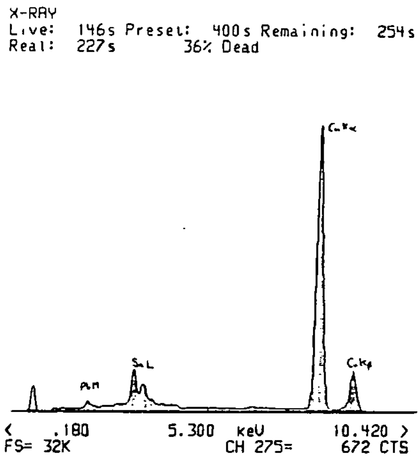


Figure 3:6 Analysis of metal inclusions in file cuts by SEM-EDXA

3.9. **Hot punches**

Nos 162 - 168. Fig. A20. Date category *A*: 163 - 167 *E*: 162, 168.

This Section is concerned with the punches which seem most likely to have been used on hot metal and therefore principally iron-smithing tools, whereas the smaller and more slender punches for cold-working techniques are discussed in Section 3.10.2. However, all of the punches included in this Section may also have been used on cold metal, or indeed intended primarily for cold-working.

The uses of hot punches during the Iron Age may have included perforating and drifting, forming, and decorating (Saunders 1977).

Punches for hot working are made sufficiently robust to enable heavy hammering, and they are either long, or rodded or hafted (like hot sets: Section 3.7) in order to keep the hand away from the hot metal (CoSIRA 1955; Bealer 1969). Iron of relatively thick section may be perforated when red hot. Today, holes are often enlarged and trued with a drift, which is in effect a punch with a long taper at the lower end of the stem and a short taper at the head, enabling it to be knocked through the perforation (CoSIRA 1955, 11, fig. 18). A punch may be used to perform the same task. Hot punches may also be used to form shoulders and intricate shapes, in which case they are normally known as fullers, the smaller ones of which are hand-held (CoSIRA 1955, 12, fig. 19). Other uses may include some functions in common with hammers, such as riveting and decorating ironwork.

The cross-sections of the lower stems of the punches discussed here range from rectangular (Nos 162 and 165) to round (Nos 166, 167, 168) and oval (Nos 163 and 164). Except for No. 162 which is flat ended, the rest have convex tips and these may therefore have been used for perforating iron, or for decorating or other purposes. No. 165 has an eye below the head, presumably for handling with rods. Nos 166, 167 and 168 may have been grasped with rods around the stems just below the heads, or they may have been used as cold punches. No. 162 with a large flat tip may have served as a fuller, possibly as a drift, or, as Manning suggests, a cold chisel (Manning 1985, 10, A29). Nos 163 and 164 may also have been used as drifts, though only No. 163 could have been knocked through a perforation.

Chronology

The probable dates for the contexts of the hot punches may be summarised as follows:

(1) 3rd - 1st centuries BC contexts: Nos 163, 166, 167.

(2) 1st century BC contexts: Nos 164, 165.

(3) unstratified (possibly post-Iron Age): Nos 162, 168.

Metalworking associations

Three punches (Nos 164, 166, 167), from Gussage All Saints, are from deposits of metalworking debris which included waste from iron-smithing as well as from bronzeworking.

Metallography

Two punches (Nos 164 and 167) have been examined by Tylecote (1975), both sampled at about mid-stem. The sample from punch No. 164 comprises ferrite and pearlite, the carbon content varying from 0.1 - 0.7% and the hardness 214-252 HV (Tylecote 1975, 6, no. 510; Spratling *et al*. 1980, 285, no. 510). The sample from punch No. 167 comprises bands of phosphoric ferrite (218-227 HV) and bands of ferrite with grain-boundary carbide (166-183 HV), the carbon content varying from to 0 - 0.15% (Tylecote 1975, 7, no. 834; Spratling *et al*. 1980, 285, no. 834). Neither punch had been heat-treated. Although the samples may not reflect the carbon content and hardness at the tip of the tools, it seems unlikely that hot punches would need to be hardened by heat treatment (cf. p. 52).

3.10. Tools for fine working

Nos 169 - 231. Figs A20 - A24. Metallography S60 - S62, S67, S68. Date category *A*: 169, 172, 173, 174, 176, 177, 178, 179, 183, 184, 186, 188, 191 - 196, 199, 201 - 204, 207, 214 - 226, 228 - 231. *B*: 175, 182, 187, 189, 190, 197, 200, 206, 212. *C*: 208, 209, 210, 213, 227. *E*: 170, 171, 180, 181, 185, 198, 205, 211.

3.10.1. Introduction

This Section comprises small struck tools, tanged tools, and double-ended implements - all tools for cold-working techniques.

Tool marks on Iron Age metalwork, and structural forms, attest the employment of a range of very different techniques of working the metal to create integral features, components, and decoration. Clearly a variety of fine-edged tool were used. Close examination of ironwork assemblages reveals a relatively large number of fine tools, or fragments of tools, many of which have never been fully published.

However, many of these tools may have been used to work other materials than metal, such as wood, bone, antler, horn, leather, shale, or pottery. Identification of small tools relies principally on an intact working edge, together with some indication of the means of holding the tool, but the condition of many does not enable full characterisation. Attribution is therefore complicated by similar tools possibly having been used for different or a variety of purposes within any one craft, or for similar or different purposes within a variety of crafts. Attribution may be assisted in the following ways:

(1) Archaeological associations

(2) Analogy

(3) Metallography.

(1) <u>Archaeological associations</u>

(i) Artifacts

Metal traces on tools suggesting therefore usage: compare for example non-ferrous metal inclusions in file cuts (above, p. 140-2), traces of bronze on Bronze Age anvils (Ehrenberg 1981), and traces of gold on touchstones from various archaeological periods (Gowland 1915, 72; Oddy 1983).

(ii) Context

Archaeological associations do not necessarily assist attribution of tools. In addition to the reasons offered earlier (p. 126), it is possible that certain crafts may have been practised alongside metalworking since many metal artifacts were furnished with sheaths, mounts, collars, or handles in organic materials, or embellishments in vitreous and other materials.

Metalworker's 'hoards', working areas, and deposits of metalworking debris offer the greatest potential for yielding small metalworking tools. The largest group of such tools from the Iron Age in Britain comes from the deposit of metalworking debris from pit 209 at Gussage All Saints. Analysis of the debris (Chapter 5.2.1) indicates that some of the iron waste derived from iron-smithing, including probably the manufacture of tools - and possibly for a number of different crafts. Nevertheless, the tools which show some evidence of use (13 of 14 discussed in this Section) would seem from their association very probably to be tools for metalworking, though the chance of an occasional tool for another purpose being present in the deposit can never be discounted.

(2) <u>Analogy</u>

(i) Comparanda

From the Continent, there are few groups of small tools which enable useful comparison. The most significant assemblage is from Manching in Bavaria (2nd to early-1st centuries BC), which has yielded evidence of cast and wrought bronzeworking, coin production and iron-smithing, and as well as for glass-working and numerous other crafts (Kramer 1960; Jacobi 1974). From Celles, Cantal there is a small group of tools (*c.* 1st centuries BC/AD), possibly from a workshop concerned principally with the working of leather and bone (Pagès-Allary *et al.* 1903; Guillaumet 1982). Sites such as Châlons, Saône-et-Loire (Reinach 1917), La Tène in Switzerland (Vouga 1923; Drack 1974), Sanzeno in Nonsberg (Nothdurfter 1979), Staré Hradisko in Moravia (Meduna 1970), and Stradonice in Czechoslovakia (Pič 1906), some of which had Roman occupation, and have each yielded a significant number of small tools but metalworking associations and stratigraphic relationships cannot be determined or are of little help in determining the function of the tools (see also Wells 1984, 161). Other sites, ones with identified metalworking areas, have yielded only a few small tools - or at least few which have been published, for example Szalacska in Hungary (Darnay 1906, 423) and Mont Beuvray Bibracte, Saône-et-Loire (Bulliot 1899; and cf. Déchelette 1914, 1543-4; Reinach 1917, 269). Current excavations at sites such as Kelheim, Bavaria (Wells 1987) and Titelberg, Luxembourg (Rowlett 1988), which have ample evidence of metalworking, may yield useful comparative assemblages of tools.

(ii) Techniques

In Chapter 2, the possibilities of employing analogies with classical and historical sources, and with recent modern workshop practice are discussed, and reasons offered why Iron Age techniques, tools, and methods of working may differ from later practice. Of particular relevance to small tools are the possible differences in manner of use and the effect that this may have on the form of the tool. Differences may include: method of holding the tool in the hand, control of the tool (*viz.* hand, wrist, or forearm), customary angle of working, force applied, and means of supporting the workpiece. Any of the first three factors could determine the size of the tool, the form of the tool stem, and the means of hafting. The Iron Age tools were unlikely to made be of uniform hardened and tempered steel as used today, and the Iron Age metalworker would probably therefore have used a different degree of force.

(iii) Tool marks and structural forms

Inference from modern practice may suggest the technique of metalworking and thus the type of tool. Furthermore, tool marks may indicate the sequence of working, and the condition of the tools. However, tool marks on Iron Age metalwork, including those intended to be seen (e.g. decorative) are frequently softened or eroded at their edges, either through finishing techniques such as burnishing or polishing, or from wear, or corrosion (Lowery *et al.* 1971, 176-7). Not surprisingly, many tool marks cannot be identified with any certainty and in some cases they are ambiguous. Nevertheless, working back from tool marks and structural forms offer the best opportunity to realise the range of techniques employed, and in many cases also the type of tool.

(3) Metallography

Metallography may assist attribution by inference from the hardness of the tools. However, few of the tools are in suitable condition to enable sampling owing to their small cross-sectional area and thus low possibility of metal surviving. Examination of the products may sometimes differentiate between the broad class of tool (e.g. struck *v.* driven), though seldom is it a feasible method of study.

The tools mentioned from Gussage All Saints (p. 145) form a basis for analysis of other groups. For the reasons outlined above, clearly attribution of many of the surviving small iron tools to a particular technique is not always feasible, though it may be possible sometimes to suggest purpose and thus a provisional identification. This Section therefore concentrates on identifying the metalworking techniques where small tools may have been employed - which may be inferred from structural form or from tool marks.

This Section is sub-divided into six categories of tools according to broad function. Within each group, the following aspects are discussed, where relevant:

(a) Type of tool and function(s)

(b) Technique(s) for which the tool type may be employed

(c) Evidence for the use of the technique during the Iron Age

(d) Characteristics of the tool type

(e) Probable and possible Iron Age examples.

The terms applied are normally those used and defined by Untracht (1982), the generally accepted authority on modern metalworking techniques, who draws his information from a variety of different modern cultures. The term 'incised' is used for decoration 'cut' into metal where the technique is uncertain, whether metal has been removed or not, as is common practice (e.g. Maryon 1938b, 188; Spratling 1972, 266; but cf. Lowery *et al.* 1971, 177-8).

3.10.2. Cold punches

Punches are struck tools, which displace or plastically deform metal, and may be used to form, pierce, finish, or decorate (Untracht 1982, 122). On other materials, punches are sometimes used today to pierce or to decorate organic materials such as leather (Salaman 1986), and it seems likely that they may have been used for similar purposes during the Iron Age.

The small iron punches are catalogued according to a combination of the size of the stem and the form of the tip (where this can be determined), in the following sequence:

(1) Medium-stemmed with round or square, blunt tips: Nos 169-183
(2) Slender-stemmed with pointed tips: Nos 184-186
(3) Slender-stemmed with dull-ended tips: Nos 187-197
(4) Other, medium-stemmed: Nos 198-203.

Comparable iron punches are known from Manching, Bavaria (Jacobi 1974, 97-102, nos 242-59, Taf. 7 and 12), and ones of less certain attribution from La Tène, Switzerland (Vouga 1923, especially pl. XLV) and Stradonice, Bohemia (Pič 1906, especially pl. XXXVIII).

Other possible iron punches from Britain are shown in Table 3:9. Three tools are mentioned earlier as possibly having had uses as punches: ?bench anvils Nos 53 and 54 (p. 98-9), and ?top-swage No. 55 (p. 101). The latter is mentioned below (p. 156), whereas Nos 53 and 54, like the probable hot punches Nos 162-168 (p. 143) are not discussed again although there is always a possibility that they may have been employed for some of the techniques included in this Section.

For some purposes, tools made in organic materials such as hard (compact) wood, antler, or bone, may have been used. Few such tools have survived or been recognised. Three bone possible punch fragments from a metalworking deposit are shown in Plate VIb (the fifth from the right is convex-tipped, the third from the right has a grooved tip).

Table 3:9 Other possible punches (not catalogued)

Site	Tool	Source	Probable date
Danebury	3 punches, wedges, or chisels	Sellwood 1984, 370, fig. 7.24, nos 2.185, 2.186 and 2.187	300-100/50 BC
Danebury	4 ?punches	Sellwood 1984, Mf 9:E12 no. 165, 9:E13 no. 206, 9:F4 no. 564, and 9:F13 no. 1294	300-100/50 BC
Gretton	?punch or chisel	Jackson and Knight 1985, 82, fig. 83.6	IA
King Harry Lane	punch	Fell 1989, 107, AN/CO, fig. 112. (burial 134)	mid-C1st AD
Meare West	?punch or chisel	Bulleid and Gray 1953, 239, I40	C2nd BC-C1st AD
Midsummer Hill	?punch	Stanford 1981, 128, fig. 59, 7	probably IA
Hod Hill	?punch	Manning 1985, 10, A30, pl. 6	IA or C1st Roman
Hod Hill	4 punches or chisels	Manning 1985, 10, A23-A26, pl. 5	IA or C1st Roman
Hod Hill	punch	British Museum (BM P1976 2-1 2)	IA or C1st Roman

The principal techniques for which there is evidence of the use of small punches are discussed below under the following headings: (a) riveting, (b) perforating and piercing, (c) doming, (d) blocking, (e) *repoussage*, (f) chasing, (g) patterning and texturing. Although there is a possibility that some of the punches may have been reserved for special purposes, it seems very probable that many were used interchangeably for a number of different purposes, as indeed punches are today (Untracht 1982, 122). Thus, although punches Nos 169-203 were very probably for metalworking, it is not possible to ascribe the tools with any certainty to any one single purpose. Examples given are therefore provisional - serving to illustrate potential function of the type.

(a) Riveting

Rivets are double-headed fastening devices which may be rigid or movable (Untracht 1982, 431). During the Iron Age, the most commonly employed means of joining metals were rivets or overlapped seams, whereas casting-on, soldering, and brazing were relatively uncommon (Spratling 1972, 261-2). Rivets were used also to join metal to other materials (e.g. scabbard plates to organic linings, and mounts to shields), to serve as hinges on some brooches, and also to secure embellishments such as perforated coral beads, and 'enamel' roundels. The majority of the Iron Age rivets are solid, but hollow cylindrical rivets are known, for example on many of the flattened bow brooches from East Yorkshire (Stead 1979, 68, fig. 25, 1) and on some 'Marzabotto' brooches (Stead 1979, 65, 94, fig. 36; 1984a, 53, fig. 20, 1). Commonly, the rivet heads were made flush particularly on functional items, others were recessed where not intended to be seen, whereas some were shaped into domed or conical heads and were thus decorative as well as functional (Spratling 1972, 262-4). Some embellishments were set with a small metal washer below the head of the rivet (e.g. Stead 1979, figs 20, 2 and 26, 2), others were set with countersunk rivets expanded with a flat-faced punch or with a pointed tool (Spratling 1972, 262, no. 322), or were attached by rivets with hollow domed washers on the reverse (Stead 1985a, 17).

Rivets may be closed with either hammers (p. 104), or punches, though only the latter can be used for countersunk rivets, and to form the heads of very small rivets (cf. Untracht 1982, 434-6).

Punches with convex ends (e.g. Nos 176, 178, 179, 180, 181, 182, 191, 192, 193, 194, 196, 201), and flat ends (e.g. Nos 197 and 202) may have been suitable for riveting.

Headed rivets may be closed with a rivet set or hollow punch (Untracht 1982, 434). Although this type of tool is not known from Britain, possible rivet sets have been identified from Stradonice, Bohemia (Ohlhaver 1939, 114, Abb. 42, 1-3; Pleiner 1962, fig. 12, no. 7; 1980, fig. 11.11, no. 11), but see also below (p. 172).

(b) Perforating and piercing

Perforations were made for rivets and studs, occasionally to initiate open-work, and were sometimes used both functionally and decoratively, for example on a strainer-plate added to a probable imported bowl from Welwyn, Hertfordshire (Stead 1967, 23-5, fig. 13, pl. V, c). The metal surrounding a perforation may sometimes be seen to be stretched and displaced indicating the use of a punch or other tool to pierce the metal (e.g. Spratling 1970b, 2). Thin sheet metal could certainly have been pierced with a sharp hand-driven tool (Section 3.10.5); other holes were drilled in the Iron Age (Section 3.11.4).

The pointed punches Nos 184-186 may have been for making small perforations in sheet metal, though No. 185 has a flattened end and may therefore have been a punch for decorating.

(c) Doming

Small hollow domes may be reproduced by blocking and stretching sheet metal into a former with the aid of a punch. Regular-shaped domes are not uncommon from the Iron Age, for example heads of studs, washers for rivets (e.g. Jope 1961a; Stead 1985a, 17), and settings for embellishments (e.g. Fox 1927). Occasionally, two-part biconvex globes were made, and although few survive in their entirety they may often be inferred from extant cups (e.g. Jope 1961a, no. 1; Jope 1982).

The three hemispherical depressions on anvil No. 49 (p. 101) were very possibly used for reproducing domes; hollows carved into wooden blocks could also have served as formers. Possible Iron Age doming punches may include No. 170 and the punch tip No. 172.

(d) Blocking and impressing

Blocking is the technique by which sheet metal is worked into or over a former, mentioned earlier concerning the use of hammers (p. 110). A similar method was probably used for the production of intricate designs on thin sheet metal, using a former below the metal, and a dull-ended punch, or an impressing tool (Section 3.10.5), to replicate the design. Patterns may also be transferred to very thin and malleable sheet metal (such as gold) by hammering a wax or lead 'force' over the sheet (Ogden 1982, 36), or punches may be used to create intaglio 'dies' in lead blocks (Maryon in Singer *et al*. 1954, 648).

Some of the motifs on the mounts from a bucket from Aylesford, Kent are replicated several times which suggests the use of a former (Stead 1971, 266). In addition, there are some vertical lines near the motifs which may indicate the extreme edge of the former (Stead 1984b, 61, pl. III, d). Other replicated marks such as six relief strips from Llyn Cerrig Bach (Fox 1946, 21-3, nos 78-81, 134 and 135, pl. V, b), a rosette strip from Stanwick, Yorkshire (MacGregor 1962, 49, no. 100, fig. 12), and some other examples (e.g. Fox 1946, 89) are considered by Spratling (1972, 445-6) probably to have been made by impressing sheet metal into a former, rather than by stamping as was originally suggested (Fox 1958; MacGregor 1962). The use of formers, certainly for large motifs, seems a more plausible method of working.

The two cast copper alloy formers from the mid-first century AD Santon hoard were probably for the production of repeat designs (Spratling 1970a, 190, fig. 4, top and lower right). One has a triskele motif, the other has a simple radiating ribbed design. These may have been used in conjunction with dull-ended punches, impressing the metal with dull-ended tools (like No. 228), or with a 'force'.

(e) *Repoussage*

Repoussage, the term derived from the French verb *repousser* 'to push again', is the technique of creating a relief design (or *repoussé* work) on sheet metal by stretching the metal from the reverse side (Untracht 1982, 118). Commonly, *repoussage* is used in conjunction with chasing (p. 154-6), and in alternating sequence - *repoussage* to create relief, and chasing to produce intaglio and to refine detail by working from the front. Punches are used to enable fine control of the design, and the workpiece is supported on a yielding material such as wood, leather, or sand-bag (Untracht 1982, 118-20).

Simple three-dimensional designs such as embossed domes and relief ribs are often also included as *repoussé* work (e.g. Spratling 1972; Stead 1985b; Eluère 1987a), such as those common on Bronze Age sheet goldwork and bronze vessels, and which continued as decorative elements on earlier Iron Age metalwork (e.g. Jope 1961a, nos 1, 2, 4, 14, pls XVIII, XIX, XXII; Fox 1927, figs 17, 18a, 18b). These methods of working may perhaps be considered as forerunners of the more complex *repoussé* work typical of the later Iron Age.

Thin sheet metal was normally employed for *repoussage*, which during working was often reduced (stretched) to much less than 0.5mm in thickness (e.g. Jope 1971, 61; Spratling 1970b, 2). The height of the relief on known examples ranges from less than one millimetre to over five millimetres above the surrounding metal (Spratling 1972, 269). High relief *repoussé* work seems to have been restricted to Britain (Stead 1985a, 33), seen typically on an early second century BC copper alloy mask shield from the Thames at Wandsworth (Jope 1976). The high-relief 'crested waves' on this shield, as on a shield from the River Witham, Lincolnshire, were exaggerated by punching in a zigzag manner from the reverse (Jope 1971, 62).

Sometimes the *repoussé* work was executed with the minimum of lines and unencumbered by secondary decoration other than simple modelling with chasing tools - simplicity which is portrayed for example on an enigmatic horse mask (1st century AD) from Stanwick, Yorkshire (Jacobsthal 1944, 99; MacGregor 1962, no. 102, fig. 13, pl. V; Megaw and Megaw 1989, 224). However, surviving artifacts suggest that *repoussé* work was more commonly outlined and accentuated by chasing, with *pointillé*, or occasionally by scoring, or engraving.

The *repoussé* work on many artifacts, including the horse mask cited above and many shield mounts, was probably created in conjunction with sinking, blocking, or raising, to form the basic shape (p. 103-4). Undercut *repoussé* decorated shield bosses, such as one from Tal-y-llyn, Gwynedd (Savory 1964, 452-4, no. 1, fig. 2), must have been largely decorated prior to final shaping over the wooden shield.

The majority of surviving examples of *repoussé* work in Britain come from the later Iron Age, on bronzework such as mounts for shields, chariots, and buckets (e.g. Megaw 1970). *Repoussé* work on scabbard plates is rare (Spratling 1972, 138-40), though two notable examples are one from the Thames at Standlake, *c.* 300 BC (Megaw 1970, no. 250), and one from Little Wittenham, Oxford, 2nd/1st centuries BC (Sherratt 1983).

Iron seems rarely to have been decorated in relief. A fragment of a possible helmet cheek-piece from Croft Ambrey (Stanford 1974, 165, fig. 76, 6) is allegedly decorated with low-relief *repoussé* work (I. Stead kindly provided this example). A sword scabbard from the Thames at Newbridge, Oxfordshire reputedly had a simple relief motif (Piggott 1950, 6, fig. 2, 2), but this may well have been an effect of corrosion - and the 'motif' no longer survives (I. Stead pers. comm.). *Repoussé* work on iron is uncommon also on the Continent (Jacobsthal 1944, 130); one example is a scabbard from La Tène (Vouga 1923, 43; Jacobsthal 1944, no. 111; de Navarro 1972, no. 66, and frontispiece).

In Britain, decoration of any type appears to have been more common on non-ferrous metals (Jope 1961a, 328), and the types of surviving metalwork which were *repoussé* worked (such as shield mounts) are more frequently known in copper alloy - and the few surviving iron umbos are undecorated. One possible reason why iron was seldom worked in relief may be due to the need for frequent annealing, and thus rapid oxidation producing scales which are less readily removed than from non-ferrous metals. However, the apparently low number may be due to lack of recognition rather than any technological reasons, though traditions or other factors may also have been involved.

Individual tool marks are rarely seen on *repoussé* worked artifacts (Spratling 1972, 120, but see no. 321, pl. 8A). Note the tool marks visible on an X-radiograph (Plate VIa) of a *repoussé* decorated bronze mount from a probable imported bucket from Marlborough (Wilts).

Today, the punches for *repoussage*, embossing, and doming are similar in form to many used for chasing (Untracht 1982, 122, fig. 5:26, 2). However, for comparable scale of work, the former tools tend to be larger and blunter (Figure 3:7a) since they function by stretching the metal from the reverse and the individual tool marks are not normally intended to be seen. The edges of *repoussé* tools are well-rounded in order to stretch the metal evenly and thus not to introduce areas of weakness in the metal.

Possible Iron Age examples are punches with broad convex tips (e.g. Nos 169, 170, 172, 179), but there is no certain evidence.

(f) <u>Chasing</u>

Chasing is a decorative technique which is normally applied to the front of sheet or cast metal, using punches to compress and displace the metal downwards and to either side. In the strictest sense, chasing (or tracing) refers to the creation of a prolonged groove or channel (Lowery *et al.* 1971, 173; Maryon 1971, 243; Untracht 1982, 118). The term is also applied to the modelling, detailing and refining of three-dimensional work, and to infills of linear work, though not to individually placed punch marks (Lowery *et al.* 1971, 173-4). Chasing is known from the second millennium BC in Britain (Rowlands 1976, fig. 1), later than embossing and *repoussage* (Eluère 1987a; 1990).

Examples of chased line work include the hatched triangular borders on a copper alloy dagger-sheath (*c.* 300 BC) from Wisbech, Cambridgeshire (Jope 1961a, no. 29, pl. XXIV). 'Laddering' was sometimes executed by chasing, for example on the sword scabbard from Little Wittenham mentioned earlier with *repoussé* decoration (Sherratt 1983; Stead 1985b, 49, fig. 66), and possibly on a copper alloy scabbard from Sutton-on-Trent, Lincolnshire (Fox 1958, 32, pl. 21; and cf. de Navarro 1972, 105, 144-5). The borders and outlining of dragon-pairs on two third century BC iron sword scabbards from the River

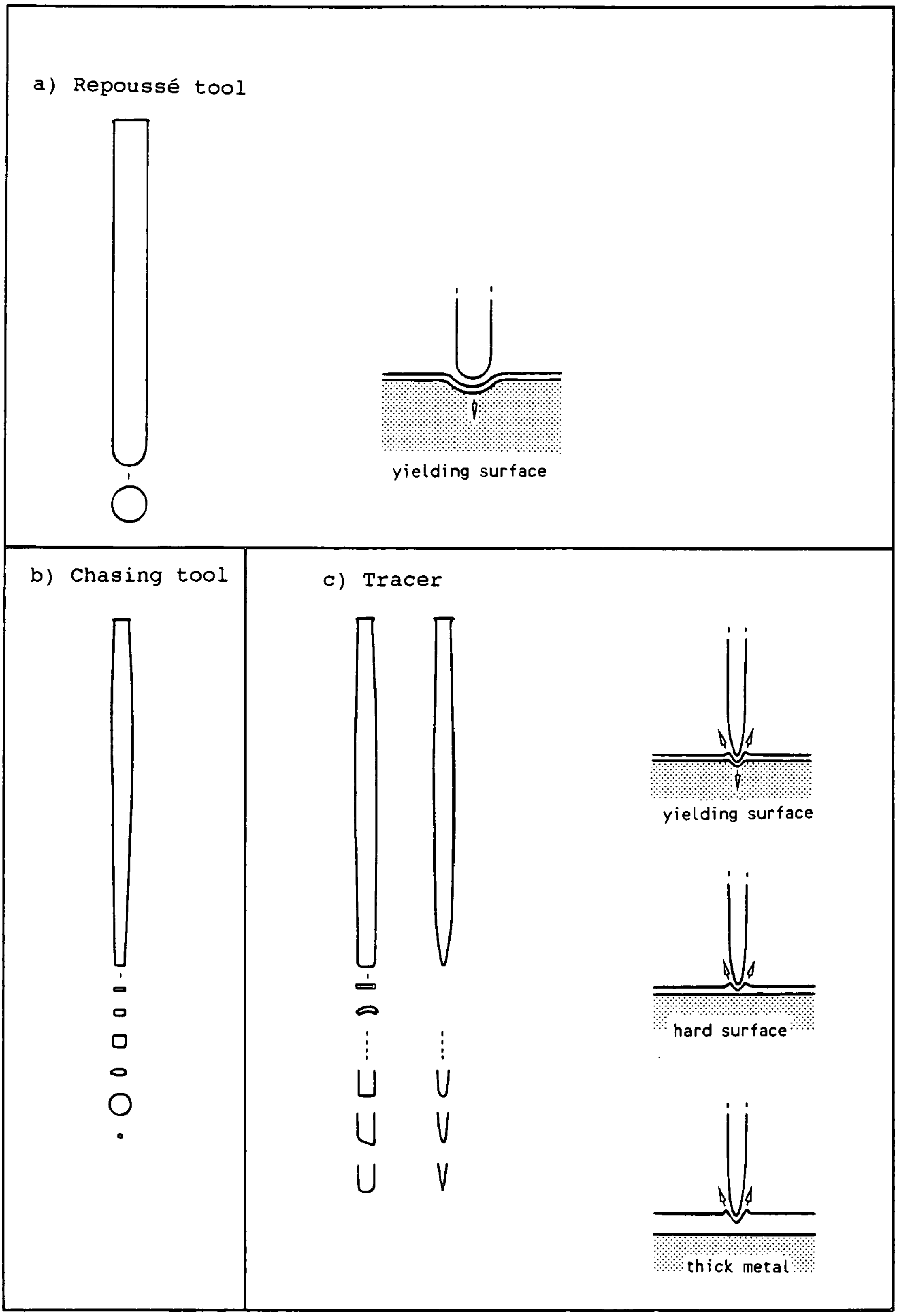


Figure 3:7 Modern repoussé and chasing tools: diagrams of principal types

After Maryon 1938a, figs 1-4; 1949, fig. 18.

Thames were chased, though these may be imported items (Stead 1984b, 269-71, pl. XXXII). Incised lines on ironwork in particular, are commonly ambiguous owing to corrosion, and it is possible that many other iron artifacts were either chased or engraved (Section 3.10.4), for example the laddering on a sword blade from Walthamstow, Essex (Stead 1984a, 47, pl. IIb), and an iron sword scabbard from Fovant, Wilts (Stead 1984a, 50, fig. 19, 3; 1985b, 20; and pers. comm.)

Today, chasing tools may be of any cross-section of stem and tip (Figure 3:7b). The prime chasing tools is the tracer or liner (Figure 3:7c), used to delineate a channel or groove, but may also be used to refine, undercut, or model (Maryon 1938a, 243-5, fig. 1; Lowery *et al.* 1971, fig 1, h and m). In linear chased work, the section of the tool mark corresponds with that of the tracer tip (Fig. 3:7c), and usually has a slight ridge of displaced metal at the side of the channel (Maryon 1938a). In general, individual tool marks from tracing are not distinguishable though occasionally on Iron Age metalwork the shape of the punch tip is betrayed by misplaced tool marks, 'feathers', or 'stitches' (e.g. Lowery *et al.* 1982, 26, pl. III, c).

The following Iron Age punches may be chasing tools:

1) Probable tracers: Nos 187, 188 and 190, all with narrow rectangular tips and rounded-off edges, slightly convex in one or both planes.
2) Possible tracers: No. 195 with a convex tip, No. 189 with a bevelled, convex tip (though this may have been a graver), and Nos 204 206 (possibly chisels).
3) Possible chasing tools for modelling: Nos 191, 192, 193, 194, 198 (convex rectangular tips); No. 201 (convex square tip); Nos 197 and 202 (flat square tips); No. 196 (convex round tip); and conceivably Nos 199 and 200 with thicker stems. ?Top-swage No. 55 may have had a modelling purpose, though the identification offered earlier is preferred for the reasons stated (p. 101).

Maryon (1938a) considers that Bronze Age tracers may have been hafted to economise on metal and to prevent burring of the head of the tool. There is a chance that some Iron Age tracers may have been hafted, though not necessarily for the reasons offered by Maryon. Of the tanged tools catalogued, only Nos 208 and 210 could conceivably have been tracers, and Nos 207, 209, 211, 213 and 215 conceivably tools for modelling, though all are more likely to have been gravers.

(g) <u>Patterning and texturing</u>

This Section discusses the use of punches for creating <u>individual</u> marks, unlike chasing, though the form of the punches may be similar. The punches discussed here are all plain with flat or convex ends. The use of patterned punches is discussed in Section 3.11.2.

The shapes of plain punch marks known on metalwork from Britain includes *pointillé* and dots, circles, arcs, lines, and dumb-bell shapes (Spratling 1972, 267, note nos 72-74, 84, 211, 243, 321, 335), triangles and ovals (Stead 1984a, 49), S-shapes (Stead 1971, 254, fig. 3) and D-shapes (Stead *et al*. 1980, 69).

Punched decoration on surviving metalwork from the earlier Iron Age often comprises rows of dots, or dot and circle motifs, on small personal items such as brooches (e.g. Harding 1972, pl. 74; Fox 1927, figs 3, 4, 5, 7, 9, 12b). On other brooches there are rows of short punched lines (e.g. Fox 1927, figs 14 and 19b) which are reminiscent of Hallstatt decoration on pins, and present on bronze pin stems from Potterne (C. Gingell, pers. comm.). Decoration on later metalwork commonly comprises individually placed punch marks applied either as spaced or almost continuous marks, and used for borders, outlines, notched edgings, infills, backgrounds, *chagrinage*, accentuation, and 'crimping'. During the later Iron Age, only *chagrinage* and 'crimping' are uncommon techniques; these were used for special effects and examples are given below.

Chagrinage is a decoration which was used on swords and iron scabbards, and is thought to have simulated the effect of a leather scabbard (de Navarro 1955, 236). *Chagrinage* is known on two probable British swords from the River Thames at Battersea, one with triangular recessed marks, the other with oval marks (Stead 1984a, 49, pl. II, e and f). Most of the known chagreened scabbards are from Switzerland, of third and second century BC date. On those from La Tène, de Navarro identified four types of punch marks: plain, ring, compound, and patterned (de Navarro 1972, 105, 145, 189-96, pl. CL).

'Crimping' may have been used to assist mechanical joins in addition to producing a decorative effect. On the outer edge of some copper alloy clad iron bridle-bit rein-rings there is a raised wavy line, for example on one from Lady's Barrow, Arras (Stead 1979, fig. 16). Sometimes, alternately spaced dots were applied on either side of the 'waves', such as on one from Llyn Cerrig Bach (Fox 1946, no.

49, pl. XXII). These 'seams' are usually considered to have secured the cladding (e.g. Fox 1946, 80), though Spratling (1979, 138) claims that they were always only decorative, the real seam occurring on the inside of the ring. Certainly this seems likely on the rings with additional decoration which is continuous with the 'seam', such as on one from Ulceby, Lincolnshire (May 1976, fig. 78). Casting of the sheet metal has also been suggested (Palk 1984, 84).

The following punches may have been used for creating various individual tool marks, for decorative or functional purposes, to produce the outlines indicated:

(1) Points: Nos 184 and 186
(2) Hemispherical: Nos 170, 181 and 182
(3) Round: Nos 180, 185, 196 and possibly Nos 173 and 178
(4) Oval: Nos 174, 188
(5) Rectangular: No. 190 and possibly No. 175
(6) Square: No. 186 and possibly No. 176
(7) Narrow line: No. 187.

Except for No. 185 which has a flat tip, the rest have marginally convex tips, or hemispherical tips (Nos 170, 181 and 182).

Spratling applies the term 'centre punch' for those which create fine tool marks such as dots, pointillé, and dot-and-circle motifs (Spratling 1972, 267); this seems a rather inappropriate (and inaccurate) use of the modern tool name.

3.10.3. Small chisels

Chisels may be used to severe, cut, chip, pierce, carve or gouge metal - as well as other materials.

The large cold chisels (Nos 106-112) which were probably for cutting thick metal are discussed in Section 3.7. Smaller chisels may have been used for cutting thinner metal, including open-work, or possibly for channelling or gouging recesses, for instance to hold 'enamel'. Scorpers (Section 3.10.4) may also have been used for the latter purpose. Open-work was frequently cast during the Iron Age, for example scabbard chapes (Piggott 1950; Jope 1961a) and a decorative disc (Fox 1947), some were made by perforating or drilling the metal and then filing (Sections 3.8, 3.10.2b, 3.11.4), whereas other items were cut. Examples of cut work on copper alloy, probably with chisels, include a dagger-sheath from the Thames at Hammersmith (Jope 1961a, no. 26, pl. XXIII, e, and p. 328), three discs also from the Thames (Smith 1905b, fig. 22; Jope 1961a, 328), and other items (Spratling 1972, 368-9, nos 268, 305, 319).

Three of the small struck tools have broad edges though none is certainly a chisel. Nos 204 and 206 may be chisels or tracers. No. 205 is damaged at the tip and may conceivably have been a punch rather than a chisel.

3.10.4. Gravers

Engraving is the technique of carving a decorative groove, but contrary to chasing (p. 154-6), metal is removed in the process (Lowery *et al.* 1971). The effect can be particularly dramatic on metalwork owing to reflectance (Penney 1975; Untracht 1982, 284), and notably when the graver is rotated to produce a zig-zag ('rocked' or 'tremolo') line (cf. Lowery *et al.* 1971, 174).

Line 'engraving', probably with flint burins, is known on bone and antler from the Upper Palaeolithic (Sandars 1968, 44; see also Maryon in Singer *et al.* 1954, 648) and on chalk from the early Neolithic (Harding 1988, 325). These materials were also occasionally engraved during the Iron Age, though most incised lines on bone and antler were probably created with a knife or a saw (Penney 1975). The use of a graver (?rolled round-nosed) or a similar tool to produce a tremolo line is known on a probable Early Bronze Age bone pendant from West Ashby, Lincs (Field 1985, 125, pl. 4). An antler weaving-comb from Meare Village West was similarly decorated (Penney 1975). Leather and wood may also have been engraved, though no evidence survives.

Engraving, both line and tremolo, seem to have been used relatively commonly on metalwork, though not before the first millennium BC, and probably dependent on steel to make the tools (Sandars 1968, 163; Lowery *et al.* 1971, 170; Ogden 1982, 44). Tremolo engraving is known on metalwork from central Europe dating to the seventh or sixth centuries BC, but the earliest examples may be on Greek pins, fibulae, and armlets dating to the eighth century BC (Jacobsthal 1952, 209-12).

On surviving bronzework from Britain, engraving was frequently employed to outline and infill motifs, for patterned borders and for shading, and was occasionally used in conjunction with *repoussé* and chased work (Megaw 1970, nos. 251 and 252). Tremolo decoration is known as early as the fifth century BC, used for the borders on a dagger-sheath from the Thames at Chelsea (Jope 1961a, no. 11, also no. 29), and for shading on fourth century BC dagger-sheaths (e.g. Jope 1961a, nos 14 and 18). The hatched 'basketry' common on first century BC/AD mirrors, apparently an insular design (Jacobsthal 1944; Spratling 1972), seems normally to have been executed by outlining and infilling with linear engraved lines (Lowery *et al.* 1976; 1982; 1983), though three mirrors are known with tremolo engraved hatchings (Spratling 1970c; Lowery *et al.* 1976, 111-2).

Iron was also engraved. A spearhead from Orton Meadows, Cambridgeshire has traces of engraved lines and arcs (Stead 1984c, 7). A sword chape from Standlake, Oxfordshire (*c.* 300 BC) is engraved on the iron cross-bridge above the copper alloy tip-plate, the latter also engraved (Jope 1961b, 76, pl. V, a and c). An iron 'saw' blade from Fiskerton (Plate Ia), possibly dating to the fourth century BC, is engraved (I. Stead forthcoming); the decoration occurs on both sides of the blade which suggests that it was not a reused weapon blade. The commonly ambiguous tool marks from either chasing or engraving, particularly on ironwork, are noted earlier (p. 156). It may be relevant that engraving produces no appreciable work-hardening of the metal, unlike chasing and *repoussage*, and therefore little or no annealing would be required during working (cf. p. 153).

Modern gravers, or burins are slender steel tools (Fig. 3:8a) made in any cross-section of stem (Fig. 3:8b). The cutting edge is ground flat, convex, or pointed (cf. Lowery *et al.* 1972, 172-3, fig. 1, b-f; Untracht 1982, 288-93, fig. 8:14). Scorpers are another type of graver, but are usually used for purposes of metal removal, such as channel cutting for inlay and the removal of background (Lowery *et al.* 1971, 173, fig. 1, g; Untracht 1982, 289). They therefore tend to have broader cutting edges.

Three main types of tremolo lines on Iron Age metalwork are distinguished by Lowery *et al.* (1971, 172-3), shown in Fig. 3:8c:

(1) The 'rocked' pointed graver (common graver and pointed oval graver) produces a central groove and barbs

(2) The 'rolled' round-nosed graver produces a curvilinear zig-zag

(3) The 'walked' scorper produces a straight-edged zig-zag.

The marks produced are affected by the width of the cutting edge, the

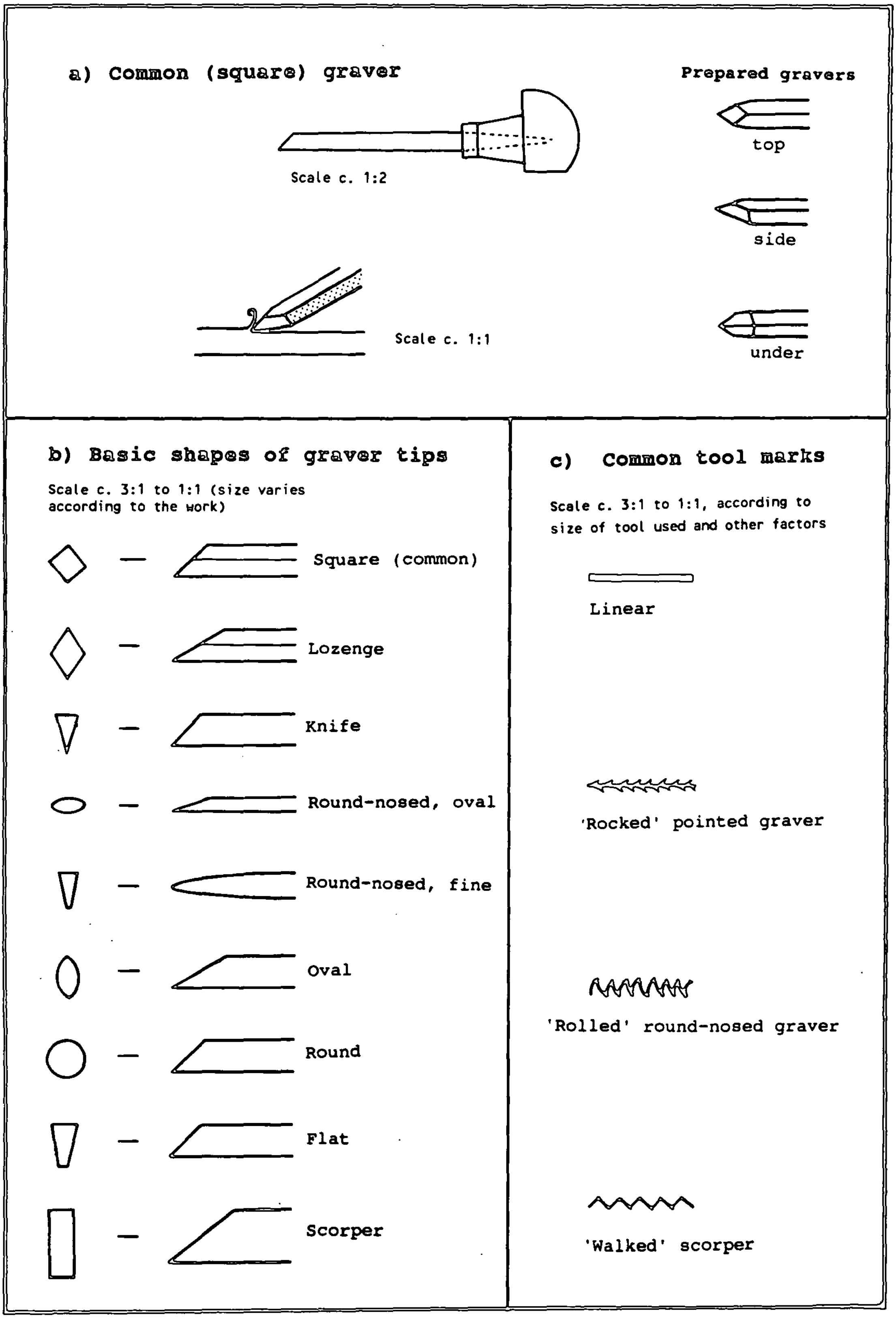


Figure 3:8 Modern gravers: diagrams showing the range and shapes of the tool tips, use, and tool marks

force applied, and the method of using the tool. Unless the tool marks can be shown to be integral to the design, whether by emphasis, regularity, or position, they need not necessarily be intentional decorative effects since tremolo lines may sometimes be produced during line engraving (Lowery *et al.* 1971, 175).

Possible Iron Age gravers are Nos 207-216, and conceivably Nos 189, 217, 218 and 221, the latter four incomplete and thus less certain. No. 189 is discussed earlier as a possible tracer (p. 156); No. 221 is more likely to be a scriber (p. 165). Nos 212, 214 and 216 have sharp bevelled tips which are rounded in sectional contour, whereas Nos 217, 218 and 221 are bevelled flat on one side. The others range from round (No. 207), oval (No. 208) to rectangular (Nos 209, 210, 211, 213, 215), and these seven are mentioned earlier (p. 156) as possible (though doubtful) chasing tools. Nos 212, 214, 216-218 could have functioned as scrapers (p. 166).

Comparable tools are known from Manching, Bavaria (Jacobi 1974, 26-7, 279, nos 229-237, Taf. 12, and possibly nos 131-140, Taf. 8).

Gravers bear a marked similarity to some leather-working awls (cf. Salaman 1986, fig. 9:10) and the term 'awl' is often applied generally to archaeological finds of tanged slender-stemmed tools (cf. Maryon 1938a, 243; Lowery *et al.* 1971, 168; Ogden 1982, 34). Such tools are not uncommon from Iron Age sites, contrary to some claims (e.g. Sellwood 1984, 354).

In Table 3:10, other short slender tanged tools are listed, a number of which could conceivably have had metalworking functions, such as engraving, scoring (see below), or modelling wax for *cire perdue* casting. Some of the tools listed have distinctly shaped tips, whereas others are simple points, but the majority are too corroded or damaged to be certain of the original form.

3.10.5. Scorers, scribers, and impressing tools

On metalwork, hand-driven pointed tools may be used for marking-out, scoring, impressing sheet metal, and other purposes (Untracht 1982). The tools may be similar or identical in form, though not necessarily in function. Terminology often applied to tool marks on Iron Age metalwork, reflected also in modern usage, derives from the tool form rather than etymology, despite possible (or necessary) alteration of

Site	Length mm	Form stem/tip	Source	Probable date
All Cannings Cross	66	r/?	Cunnington 1923, 125, pl. 20, 6	earlier IA
All Cannings Cross	75+	?c/?v	Cunnington 1923, 125, pl. 20, 7	earlier IA
All Cannings Cross	78+	s/u	Cunnington 1923, 125, pl. 20, 8	earlier IA
All Cannings Cross	42	c/v	Cunnington 1923, 125, pl. 21, 6	earlier IA
Bagendon	93+	c/-	Clifford 1961, pl. XLVIII, top mid.	C1st AD
Bagendon	37+	s/-	Clifford 1961, pl. XLVIII, lower mid.	C1st AD
Bagendon	55+	c/v	Clifford 1961, pl. XLVIII, mid. rt.	C1st AD
Bagendon	54+	c/u	Clifford 1961, pl. XLVIII, lower rt.	C1st AD
Barbury Castle	140	c/?c	MacGregor & Simpson 1963, fig. 2, 18	later IA
Bredon Hill	80	c/u	Hencken 1938, 80, fig. 9, 6	later IA
The Breiddin	150+	s/o	C. Saunders forthcoming (no. 206)	IA or Roman
Croft Ambrey	63+	r/u	Stanford 1974, 174, fig. 82, 13	C3rd - C2nd BC
Croft Ambrey	62+	c/u	Stanford 1974, 174, fig. 82, 14	C3rd BC
Danebury	100	c/?u	Sellwood 1984, Mf 9:F4, SF497	400-300 BC
Danebury	102	c/-	Sellwood 1984, 354, 2.56, fig. 7.13	300-100/50 BC
Glastonbury	71+	?s/-	Bulleid & Gray 1911, 388, I43, pl. LXI	C2nd BC - C1st AD
Glastonbury	71+	c/x	Bulleid & Gray 1911, 388, I74	C2nd BC - C1st AD
Ham Hill	115	r/x	Somerset County Museum A669	IA or Roman
Ham Hill	81	r/x	Somerset County Museum A670	IA or Roman
Ham Hill	121	c/v	Somerset County Museum A1506	IA or Roman
Ham Hill	105	?c/-	Somerset County Museum A1522	IA or Roman
Ham Hill	107	r/x	Somerset County Museum G'19	IA or Roman
Hod Hill	90	c/v	Manning 1985, 40, E17, pl. 16	IA or C1st Roman
Hod Hill	90	s/x	Manning 1985, 41, E27, pl. 16	IA or C1st Roman
Hod Hill	97	r/u	British Museum BMP1960 4-5 3271	IA or C1st Roman
Maiden Castle	52	?	Wheeler 1943, 272, fig. 89, 4	early C1st AD
Meare West	25	c/u	Gray & Bulleid 1953, 239, I6, fig. 65	C3rd BC - C1st AD
Meare West	84+	c/-	Gray & Bulleid 1953, 239, I8	C3rd BC - C1st AD
Meare West	94+	c/-	Gray & Bulleid 1953, 239, I9, pl. LI	C3rd BC - C1st AD
Meare West	71+	c/-	Gray & Bulleid 1953, 240, I62	C3rd BC - C1st AD
Meare West	61+	c/-	Gray & Bulleid 1953, 240, I90	C3rd BC - C1st AD
Meare West	46+	c/-	Gray & Bulleid 1953, 240, I112	C3rd BC - C1st AD
Meare West	77	o/-	Gray & Bulleid 1953, 247, I115	C3rd BC - C1st AD
Midsummer Hill	69	c/-	Stanford 1981, 128, fig. 59, 6	IA
Mynydd Bychan	55	c/v	Savory 1955, 44, fig 4, 4	C1st BC/AD
Rudston	76	?c/u	I. Stead forthcoming (B. R141, FN/BF)	IA
Swallowcliffe Down	141	s/u	Clay 1925, 82, pl XI, C5	?IA
Swallowcliffe Down	141+	s/-	Clay 1925, 82, pl XI, C6	?IA
Swallowcliffe Down	97+	c/-	Clay 1925, 82, C7	?IA
Twyn-y-Gaer	91	c/u	L. Probert forthcoming (412-79)	IA
Wookey Hole	72+	c/-	Balch 1911, 576, 2092	later IA
Wookey Hole	70	c/u	Balch 1911, 576, 2092	later IA
Wookey Hole	104	c/u	Balch 1911, 576, 2092	later IA

c = circular o = oval r = rectangular s = square v = point
w = wedge u = blunt x = spatulate + = incomplete - = lost

Figure 3:10 Other tanged implements (not catalogued) the tools for the different functions. Scoring, whether functional or decorative, is defined by Untracht as 'a controlled form scratching, scribing, or scraping, terms that relate to the degree of the groove depth in the result' (Untracht 1982, 299).

Similar tools may have been used on metals for piercing (p. 150-1), and in other crafts for piercing (e.g. leatherworking), marking, modelling, and probably for many other purposes. Furthermore, within any one craft, pointed tools may have been used for different purposes; in metalworking, a sharp tool such as a graver or fine punch may equally have served (or been intended for) the purposes indicated above. Thus attribution of pointed tools to a particular purpose, or craft, is never certain and is probably impossible.

The uses of the hand-driven tools with sharp or dull-ended points included in this Section, for which there is some evidence on Iron Age metalwork include:

(1) Functional scoring, e.g. scribing or marking-out (Lowery *et al.* 1971, 172; Untracht 1982, 299-301)

(2) Decorative scoring

(3) Impressing: where metal is pressed (or scored) onto a hard yielding surface to create a smooth-edged groove, or pressed into a mould (p. 151)

The condition of tool marks seldom enables attribution of purpose or technique though this may sometimes be inferred from position or depth of mark. The difference between (1) and (2) above is in function; the difference between (2) and (3) - but excluding the use of moulds - may be degree of pressure applied and sometimes also tool sharpness. The metalworking uses are discussed under two headings.

Functional scoring (scribing or marking-out)

There is evidence from Iron Age metalwork that designs were transferred from templates and patterns, sometimes with the aid of a scriber, or with compasses (Section 3.11.1). Where inscribed guide-lines are not visible on complex work, it is generally assumed that they had been erased by subsequent work or by wear, or that the guide-lines had been marked onto a surface coating of a material such as wax or grease (Lowery *et al.* 1976, 120-2; Savage *et al.* 1982, 464).

The use of a template is suggested by the irregularity of the engraved arcs on a fourth century BC dagger-sheath from the Thames at Hammersmith (Jope 1961a, no. 18, pl. XXI, c, and p. 328). Tool marks such as the guide-lines on the mirrors from Great Chesterford, Essex, and Old Warden, Bedfordshire (Spratling 1970c; Lowery *et al*. 1976) and on a shield boss from South Cadbury (Spratling 1970b, 12), attest free-hand marking-out with sharp narrow implements.

The simplest marking-out tool is the scriber, which today, are slender steel rods with pointed and polished tips (Untracht 1982, 299, fig. 8:28, 2 and 3). A scriber may be devised from a hard sharp material such as flint, or from any pointed implement or fragment of hard metal rod (Lowery *et al* 1971, 172, fig. 1, a; Untracht 1982, 299).

During the Iron Age, there seems no reason why specially made tools, or at least favourite implements or reformed broken tools, would not have been used for the marking-out of complex designs - rather than anything sharp at hand. By analogy with modern tools, Nos 219-226 are possible candidates. The slender fine-tipped punches Nos 185 and 186, and gravers Nos 212, 214, 216, 217 and 218, could equally have served as scribers. There seems no reason why some scribers may not have been hafted, like No. 227, included here because of its possible association in a hoard with other metalworking tools. Other tanged implements are shown in Table 3:10, some of which are pointed.

<u>Decorative scoring, and impressing</u>

'Scored lines' decorate the iron sheet which covers the wooden pommel on a sixth century BC dagger-sheath from the Thames at Mortlake (Jope 1961a, no. 1, pl. XVIII, see also no. 19; Jope 1982). Scoring, with a blunt-ended tool, was used to accentuate relief ridges on another early dagger-sheath (Jope 1961a, no. 12, and p. 328). Scoring (or ?impressing) was sometimes used in conjunction with *repoussé* work, for example to represent human hair on a brass anthropoid plaque from Tal-y-llyn, Gwynedd (Savory 1964, fig. 6), and to represent human hair and horse's manes on mounts from the imported bucket from Marlborough, Wiltshire (Fox 1958, 68-70, pls 34, 35 and 36), the tooling clearly visible on the X-radiograph (Plate VIa). The shallow U-shaped outlines of the curvilinear design on a sword scabbard from Isleham, Cambridgeshire (Stead *et al*. 1980) may have been scored - a 'scriber' is the suggested tool - though this attribution is uncertain (I. Stead pers. comm.; Stead *et al*. 1980, cf p. 67 and p. 69).

The tools used for decorative scoring may very well, and probably were, the same as those used for scribing. There seems no reason why a short knife-blade may not have been used for scoring (or for impressing); 'knifing' has been suggested as the means of decorating some Bronze Age goldwork (Eluère 1990) and Iron Age bone and antler (Penney 1975). Where greater control of the work was needed, short-stemmed tools may have been used, such as Nos 228 and 229. The former has a dull-ended tip and was possibly hafted. Other possible examples may be found in Table 3:10.

3.10.6. Scrapers

Scrapers are used today to clean off excess metal such as solder, burrs from engraving, and casting flaws, or to remove unwanted tool marks. Modern scrapers are hafted, with a cutting edge(s) extending along the stem (Untracht 1982, 93, 405, fig. 8:25). Some can be used in a rotary action to enlarge perforations, in which case they are usually known as broaches or reamers. Larger versions (i.e. augers and drill bits) were used in the later Iron Age for woodworking (e.g. Manning 1985, 28, B75 and B76; Jacobi 1974, Taf. 10).

Scrapers may have been used during the Iron Age to pare down metal to create a relief design, described by Spratling as 'false relief' work (Spratling 1972, 268, nos. 133, 163, and 469). Spratling cites an example of a possible drilled and reamed rivet-hole on a shield boss from South Cadbury (Spratling 1970b, 21). Apart from these examples, which are in any case rather dubious evidence of the use of scrapers, there seems to be no certainty of their employment on metalwork, probably because obvious tool marks would not be produced.

Tools which may have had finishing purposes are No. 230, which may also have served as a burnisher, and conceivably therefore a multi-purpose tool, and No. 225, possibly for enlarging perforations. A number of the tools catalogued as gravers could also have been used as scrapers (e.g. Nos 212, 214, 216, 217, 218). Other tools such as chisels and knife blades may also have served these purposes.

3.10.7. Burnishers

Burnishers are used to smooth or polish metal - by compressing the surface layer, but no metal is removed in the process. Their typical use is therefore as finishing tools; they may also have been used in the Iron Age to apply claddings and other types of embellishment, to close or smooth small rivets, and possibly for polishing wheel finished vessels (p. 104). In other crafts, similar uses may have included compacting and polishing 'enamel', and smoothing or polishing organic materials - or similar types of tools may have been used for other purposes than finishing. The arguments are circular, like many of the other tool groups discussed above - does the tool type fit the function, which in the case of burnishers are unlikely to leave clear tool marks - or was a completely different type of tool used in the Iron Age?

Blunt-ended punches may be used to burnish metal, though today, burnishers are usually hafted tools with short, well-rounded and highly polished stems (Untracht 1982, 638-9, figs 14:4 and 14:5). Polished pebbles, hard wood rods, bone, or antler implements (e.g. tines) may also have been used in the Iron Age.

Possible hafted burnishers are Nos 228, 230 and 231. No. 228 is discussed earlier as a possible tool for impressing (p. 152); No. 230 may have functioned also as a scraper.

Chronology

The probable dates for the archaeological contexts of the small tools may be summarised as follows:

(1) 5th - 3rd centuries BC: Nos 188, 194, 219. Others potentially early: Nos 172 and 183.

(2) 3rd - 1st centuries BC: Nos 173, 174, 176, 184, 195, 196, 199, 201, 223, 224, 225, 226, 229, 231.

(3) 1st century BC: Nos 169, 179, 186, 191, 192, 193, 202, 204, 207, 215, 216, 217, 218, 221, 228, 230.

(4) 1st centuries BC and AD: Nos 175, 177, 178, 182, 190, 197, 203, 220, 222 (some are closely dated within this range).

(5) 3rd or 2nd century BC to mid-1st century AD: Nos 187, 189, 200, 206, 208, 209, 210, 212, 213, 214, 227.

(6) later Iron Age or early Roman: Nos 170, 171, 180, 181, 185, 198, 205, 211.

Metalworking and other associations

(1) Seventeen tools are from deposits (presumed dumps) of metalworking debris derived from bronzeworking and iron-smithing at Gussage All Saints: pit 209 - Nos 169, 186, 191, 192, 193, 202, 207, 215, 216, 217, 218, 221, 228 and 230; pit 437 - Nos 174, 199 and 229. Eight tools are from other features at Gussage All Saints, but were not

associated with metalworking debris (Nos 175, 182, 188, 190, 194, 195, 196, 197), though No. 194 may have had connections.

(2) Deposits of mixed metalworking debris at Weelsby Avenue yielded Nos 179 and 204.

(3) No. 222 is from a probable metalworking area at South Cadbury.

(4) The four tools from Meare Village West (Nos 187, 200, 206, 212), and one from Meare Village East (No. 189) are from areas which yielded metalworking debris or other metalworking tools, though stratigraphic correlations cannot be determined.

(5) Six tools are from hoards which comprised other metalworking tools (Nos 172, 208, 209, 210, 213, 227)

(6) From other sites with metalworking activity, but the tools not associated with metalworking debris, occurring mostly in deposits containing domestic rubbish: Nos 173, 176, 177, 178, 181, 183, 184, 185, 201, 203, 205, 211, 214, 219, 220, 223, 224, 225, 226 and 231 (Nos 223 and 224 are from the same layer in a pit at Danebury; Nos 225 and 226 are from the same feature and layer at Croft Ambrey).

(7) Four tools are unstratified (Nos 170, 171, 180, 198).

Technology

It is possible that tools made of hard wood, bone or antler were used for some of the techniques described in this Section. In particular, these may include certain types of punches for working sheet metal, such as *repoussé* tools (Maryon 1938a, 249; Ogden 1982, 35), tools for impressing, and burnishers. Where a longer life is required of tools, and for certain techniques including engraving and chasing, tools in bronze, iron, or steel are needed (Lowery *et al.* 1971, 170). Bronze tracers have been found to be inconvenient to use on bronze, since they require continual reforming of the tips (Lowery *et al.* 1971, 170). Stone tools are considered to be unsuitable for engraving metal owing to their brittleness (Ogden 1982, 44).

Although gold may be engraved with bronze tools (Eluère 1990), bronze cannot be made sufficiently hard to engrave bronze (Maryon 1938a, 243; 1949, 117-8; Sandars 1968, 163; Young 1970, 88; Lowery *et al.* 1971, 170). Evidence of the use of damaged gravers occurs on a mirror from Old Warden (Beds) and on a shield mount from Llyn Cerrig Bach (Spratling 1970c, 10-11, pl. 3). It is normal procedure today to continually resharpen a graver, and it may be that the metalworkers who made these two items were less practised, rather than the tools having been of poor quality. The decoration on the Old Warden mirror, once described as 'frighteningly mad disintegration' (Sandars 1968, 268), is perhaps atypical of Iron Age craftsmanship. Other engraved items attest poor workmanship, for example a mirror from Aston, Herts, and a spearhead from the Thames at Datchet (Lowery *et al.* 1982).

Gravers in particular are submitted to high stress during use, and especially when rocked since pressure is applied to the corners to the tool edge. Mention is made earlier (p. 49) to experiments conducted by Maryon on gravers of various bronze compositions (Maryon 1949, 117-8). In these experiments, gravers made of 5%, 10% and 20% tin bronze were used, but only the 20% tin bronze tools are reported to have survived more than a few rockings even when used on copper, though the (tremolo) tool marks were produced more through pressure than by a cutting action. Furthermore, the same tools did not function well when used to engrave straight lines on gold or copper, and did not cut at all on bronze.

In similar experiments, the writer has tried gravers devised from 30% zinc brass, 5% tin bronze, and low-phosphorus ferritic iron. The hardness of these devised tools in their work-hardened (as made) condition was between 160 HV and 200 HV - appreciably higher than the copper sheet (92 HV as purchased, before annealing). In addition, flint burins knapped with robust edges were tried (supplied by P. Harding). The results were similar to those reported by Maryon (1949). None of the gravers withstood more than a few 'rockings'; the metal gravers blunted rapidly, the flint tools splintered at their edges and corners, and the tool marks rapidly decayed as the tools became damaged. It would seem, therefore, that even a hardness of *c.* 100 HV over the metal being worked is insufficient to enable a cutting action and prevent damage to the tool.

It is of relevance that the surface of an engraved iron 'saw' blade from Fiskerton (Chapter 5.5.b and Plate Ia) comprises low-carbon (pearlitic) iron in the air-cooled condition (S69). This suggests that the graver which was used to decorate the blade was very probably made of hardened steel (e.g. high-carbon, or quench-hardened).

<u>Metallography</u>

Two small punches have been examined by Tylecote (1975). The sample from punch No. 169 comprises 0.6-0.8% carbon (ferrite plus spheroidizing pearlite), hardness 274-296 HV5 (Tylecote 1975, 6, no. 575;

Spratling *et al.* 1980, 285, no. 575). Punch No. 198 comprises coarse-grained (?phosphoric) ferrite of hardness 202 HV5. (Tylecote 1975, 7, no. 824; Spratling *et al.* 1980, 285, no. 824). Both of these punches were sampled at about mid-length; although the samples may not reflect the structure and hardness at the tips, it seems very unlikely that either tool was heat-treated.

Three other catalogued tools have been examined: ?graver No. 208 (S60), and ?scorers/scribers No. 219 (S61) and No. 220 (S62). A further two tanged implements, listed in Table 3:10, were examined for comparison (S67 and S68), both from All Cannings Cross (Cunnington 1923, 125, pl. 20, nos 6 and 8). These five tools were originally sampled by Ehrenreich (1985) for elemental analysis.

The sample from ?graver No. 208 comprised medium to high carbon steel but the structure was well-annealed and the hardness only moderate (176 HV). ?Scorers Nos 219 and 220 comprised low-carbon iron, hardness 103 HV and 207 HV respectively, the latter of high hardness due to small grain size. S68 also comprised low-carbon iron (176 HV). S67 comprised medium to high carbon steel, and revealed a small amount of martensite, plus irresolvable pearlite (270 HV); this structure, although typical of slack-quenching, could have resulted from fast air-cooling in a rod of this small cross-section.

Thus, of these five hand-driven tools, only ?graver No. 208 and the tanged implement (S67) from All Cannings Cross (potentially a graver or scorer) are hardened through the use of steel, but neither can be considered to have been additionally hardened by quenching.

3.11. Other tools

Included in this Section are five types of tools which have not yet been recognised from the area of study, but tool marks on metalwork from Britain suggest their employment, or possible examples of the tools are known from the Iron Age on the Continent.

3.11.1. Compasses

The use of adjustable compasses may be inferred from complex designs (Frey and Schwappach 1973; Frey 1976; Frey with Megaw 1976). Tool marks in the form of shallow regular arcs on metalwork attest the use of compasses from the fourth century BC onwards in Britain, either for laying-out designs (Jope 1961a, no. 14, pl. XXII), or for creating motifs or designs (Jope 1961a, no. 23, pl. XXI, c and e; Stead 1984a, 49, fig. 17, 2). These are early (4th or 4th/3rd century BC) examples on weapon sheaths made in copper alloy, or iron; adjustable compasses are indicated in one case (Jope 1961a, no. 14).

The design on a mirror from Holcombe, Devon (earlier 1st century AD), was also constructed with the aid of adjustable compasses (Fox and Pollard 1973; Lowery *et al.* 1976; Lowery and Savage 1976). Traces of evenly spaced parallel lines, 0.1mm or less in width, indicate slippage during use of the compasses (Lowery *et al.* 1976, 100, pl. XXI). Frey considers that most of the British mirror designs were marked-out with compasses (Frey 1976, 61), though Lowery *et al.* (1976) demonstrate that many of the 'guide-lines' were drawn freehand.

Part of a possible small iron compass was found at Lough Crew, Co. Meath (Crawford 1925, 15, 23). This was found with several hundred pieces of worked bone, many of which bear compass-drawn decoration, assigned stylistically to the late first century BC or early first century AD (Crawford 1925; Megaw and Megaw 1989, 206, fig. 347). A complete compass was found at Tumulus de Celles, Cantal (Pagès-Allary *et al.* 1903, 394-5, no. 10, fig. 13) in a group of tools which may have been the remains of a workshop principally for the working of bone and leather (Guillaumet 1982).

3.11.2. Patterned punches

Patterned punches - with flat, cameo, or intaglio decorated tips - may be employed to produce complex motifs (Ogden 1982, 36-9; Untracht 1982, 152-3), those in metal were probably not easily made in the Iron Age. Coin dies are another category of these tools, and are discussed in Section 3.11.3.

Although no patterned iron punches are known from Britain, their use is attested from stamped relief motifs on sheet metal, hollow punch marks, and discrete recessed punched marks on weapon blades.

The use of patterned punches on sheet metalwork in gold and in bronze, mostly in relief, is known from the Bronze Age on the Continent (Eluère 1987a; Ogden 1982). Stamped decoration seems to have been little used in Britain before the first century AD (Megaw and Megaw 1989, 228-31, fig. 391). Very simple 'stamped' marks, such as relief rings with central bosses, occur on early dagger-sheaths (Jope 1961a; nos 5 and 14), and on later Iron Age metalwork such as on a bucket from Baldock, Herts (Stead 1971, fig. 3, d-f), and sheeting from a possible box from the Lexden Tumulus, Essex (Foster 1986, 75-6, fig. 26). Some repeat motifs on copper alloy strips were likely to have been impressed into a mould (p. 151).

Hollow punch marks are known on several items of metalwork from the later Iron Age. Circular hollow punch marks are used decoratively (Spratling 1972, nos 84, 211, 243, 321), and possibly also functionally (Clarke 1954, 37-9, pl. II). Hollow lozenge-shaped punched marks occur along the strips bordering the spine on the recently discovered copper alloy shield from Chertsey, Surrey (I. Stead pers. comm.).

Discrete punched marks are known on five swords (Stead 1985b, 50), including a delta motif on a sword from Llyn Cerrig Bach (Savory 1965), and a mark showing a pig on a sword from West Row, Suffolk (Stead 1985b, 50, fig. 68). The latter was stamped three times, twice on one side, and once on the other. Another mark, on a sword from Isleham (Cambs), survives only intermittently, though it too was probably punched (Stead *et al.* 1980, 70-1, fig. 1). Thirteen swords from La Tène (Switzerland) are similarly marked; none of the marks is duplicated, and it has been suggested that they may be armourer's marks (Vouga 1923, 35-6, fig. 6).

Iron ring punches are known from the Continent, though none need necessarily have been used on metalwork, and tools for leatherworking seem possible alternatives. A hollow ring-punch is known from Celles, Cantal (Pagès-Allary *et al.* 1903, 396, fig. 18; de Navarro 1972, 190). From La Tène there are three ring-punches; one for producing two concentric circles, another for producing a ring with a raised centre, and the third is a circular punch (Vouga 1923, 115-6, pl. XLVI, 17, 24 and 27; de Navarro 1972, 190, pl. CXLVIII, 3). Only two of these four punches are stemmed (Vouga 1923, pl. XLVI, 17 and 27). Other possible ring punches may be tools from Stradonice, identified (Ohlhaver 1939) as rivet sets (p. 150).

3.11.3. Coin dies

In Britain, coins were struck from the earlier part of the first century BC (Haselgrove 1987). Although no coin dies are known from Britain, a number have been found in France - at Avenches, Bar-sur-Aube, Corent, Mont Beuvray, and St. Symphorien d'Ancelles (Collis 1985, 103). Others are known from Spain (Cooper 1988, fig. 2), and a hoard of anvils and stocks was found at Szalaska, Hungary (Darnay 1906, figs 1, 3, 5, 7 and 9).

The majority of the surviving coin dies of Iron Age or Roman date are apparently made of bronze (Wheeler 1936, 222-3, fig. 49; Sellwood 1976; 1981; Collis 1985; Van Arsdell 1989, 50), or 'bronze' set into iron casings (Avenches: Drack 1974, 130, Abb. 26, 13). A few are known in iron or steel (Tylecote 1986, 118-9), but it is possible that a greater proportion of dies in iron or steel have failed to be recognised (Sellwood 1981).

Roman bronze dies have been found to comprise upwards of ten per cent tin, but a die 'from a Celtic site' comprises only seven per cent tin (Sellwood 1981). Some British Iron Age coins, notably those of silver, were struck with relatively soft dies or dies which were worn or damaged (Van Arsdell 1989, 50-1). It is noted earlier (p. 41) that bronze dies may be used effectively providing that the metal is struck hot. Sellwood (1976; 1981) considers that the Roman dies were probably made by a combination of drilling and engraving to produce the intaglio design, much in the way that contemporary seal-stones were made. However, there seems no reason why bronze dies may not have been cast, and perhaps even from hubs made of iron (Grierson in Singer *et al.* 1956, 486; Tylecote 1986, 118). The Iron Age bronze 'poinçon monétaire' from Halloy-les-Pernois, Somme, the design positive, may have been for producing coin dies; striking rather than casting is suggested (Fournier *et al.* 1989). The number of estimated Iron Age coin dies (Haselgrove 1987, table 3:1) suggests that manufacture was not overwhelmingly time consuming nor technically difficult.

3.11.4. Drills

There is evidence that drills were occasionally used to create small holes on later Iron Age metalwork. At least some of the (original) rivet holes on a shield mount from the Thames at Battersea were drilled (Stead 1985a). A fibula from Danebury has two drilled holes on the foot, possibly intended for later enlargement to an open-work design (Jope in Cunliffe 1984b, 343, no. 1.26). One of the rivet-holes on a shield boss from South Cadbury is considered to have been drilled and later enlarged by reaming (Spratling 1970b, 2).

Depictions from the classical world of the drilling of wood and stone invariably show the bow-drill (Childe in Singer *et al.* 1954, 187-92; Goodman 1964; Gaitzsch 1980). However, the pump-drill, operated in one hand only offers greater versatility. It may have been used in antiquity (Coghlan 1951,102; Childe in Singer *et al*. 1954, 190), like today for metalworking (Untracht 1982, 252, fig. 4:80), though there is no direct evidence for its use in the Iron Age.

A chalk disc, conceivably the flywheel from a pump-drill (Stead 1985b, 9) was found close to a hammer (No. 67) and a file (No. 131) in an early first century AD burial at Whitcombe (Chapter 5.6c). Other perforated discs made of stone or other suitably heavy material, commonly found on Iron Age sites (e.g. Brown in Cunliffe 1984b, 425) and often considered to be spindle-whorls, may also have been flywheels from pump-drills. Drill-bits for metalworking were presumably made of hardened metal (Sandars 1968, 163), but none is known, and perhaps they are unlikely to be recognised.

3.11.5. Draw-plates(?)

Rod or wire of small cross-section was used in the Iron Age for rivets, studs, pins, chain, mail, and for other functional or decorative purposes. Seldom has the condition of wire enabled the method of production to be determined with any certainty, except if the metal is gold, or if pronounced hammer marks or longitudinal facets are present. Ambiguous striations may be caused by polishing or burnishing, or by swaging to 'true' the wire (Ogden 1982, 48).

Today, wire is made by pulling (drawing) rod under tension through plates perforated with tapered holes (draw-plates), but the technique is really only appropriate for wire of less than 2mm diameter (Ogden 1982, 51; Untracht 1982, 150). Iron wire cannot be drawn by hand methods, and tin and lead are too weak in tension to be drawn (Tylecote 1987, 269-271; Samuels 1988, 35-7).

Drawn wires and draw-plates are known from the early medieval period (Oddy 1977), and there have been occasional claims of drawn wire from the Iron Age and Roman periods (cited in Oddy 1977; 1979; Thomsen and Thomsen 1974; 1976). More certain evidence for early techniques are hammering, folding, 'block-twisting' of rod, and 'strip-twisting' of sheet, all of which are known on Bronze Age and later gold jewellery from the Continent (Carroll 1972; Oddy 1977; 1980b; 1987; Ogden 1982). Hammered wires and block-twisted wires are known from the Bronze Age in Britain (Oddy 1987), though to date, only hammered wire is known from the Iron Age (e.g. Clarke 1954).

Possible Iron Age (or early Roman) iron draw-plates are reported from the Continent; two from Staré Hradisko in Czechoslovakia, and two from Sanzeno, Nonsberg (Jacobi 1979). However, these may have had other functions, such as tools for heading nails (cf. Pleiner 1980, fig. 11.11, no. 14). They do, however, bear a remarkable resemblance to many presumed draw-plates from later periods (e.g. Ohlhaver 1939, 75-80, Taf. 43, and cf. Taf. 45, 1 and 2; Thomsen and Thomsen 1974, figs 5 and 6; Oddy 1977, fig. 4), but until wire which has definitely been drawn is determined from the Iron Age and Roman periods, nail forming or similar functions are preferred.

Two so-called bronze draw-plates were found in the Late Bronze Age founder's hoard at Isleham, Suffolk (Britton 1960, 281; Rowlands 1976, 16; P. Northover pers. comm.). However, the holes are relatively large for drawing wire, and it has been suggested that these may have been swages for the shaping of tubing, the trueing of twisted wires, or for other purposes (Ogden 1982, 51; A. Oddy pers. comm.). A perforated gritstone pebble found with gold torcs at Snettisham (Hoard A) may also have had similar functions though the cross-section of the hole is rather irregular (Clarke 1954, 39, fig. 6).

At present, there seems to be no unequivocal evidence for the drawing of wire in the Iron Age.

CHAPTER 4

THE METALLOGRAPHIC EVIDENCE

4.1. <u>Introduction</u>

The results of the metallographic examinations (Appendix B) of individual tools are discussed under the relevant Sections in Chapter 3. This chapter is concerned with the metallurgical evidence from the full range of metalworking tools examined and discusses mainly evidence of enhancement of properties in the tools - principally therefore carburization, forging, welding, and heat treatments.

The basic iron-smithing processes are described in Chapter 1.3.3. Some aspects are discussed further where relevant to the interpretation of the samples in terms of properties of the raw metal (Section 4.2), hot mechanical work (Section 4.3), and hardening techniques (Section 4.4). In order to examine technological trends, the results from the metalworking tools are compared with other categories of Iron Age artifacts from Britain (Section 4.6.1) where results are available from published sources (Table 2:1). Technological affinities are sought with tools for other crafts from Britain (Section 4.6.2), and with metalworking tools of similar date from six sites on the Continent (Section 4.7). Section 4.8 summarises the principal findings and conclusions.

A total of 47 presumed and possible metalworking tools is discussed, comprising 6 hearth implements and 41 edge tools (Figure 4:1). Where it is relevant to identify the individual tool, type of tool, sample number, site, or date, this is included, otherwise these details may be gained by reference to Appendices A - C. The source and content of the samples is outlined in Chapter 2.5.1. Except where stated, the results from the seven comparative tools (S63-S69) are not included in this Chapter, nor is S46, a sample of corrosion products which gave inconclusive results.

In general, the edge tools are distinguished as a group from hearth implements in the following discussion, principally because

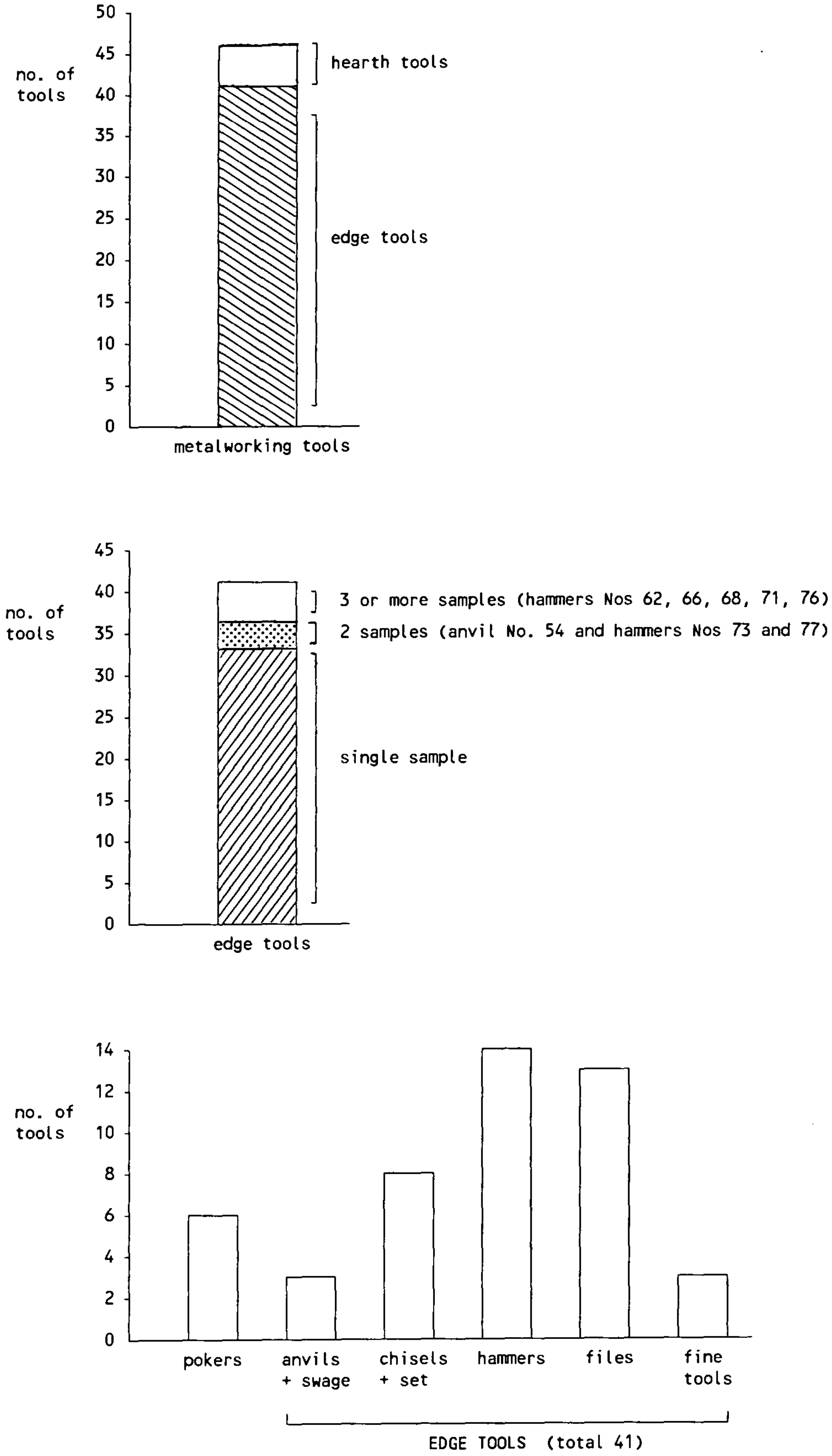


Figure 4:1 The metallography sample population

they may be expected to have enhanced metallurgical properties, and also because the metal structures of hearth tools may be altered by normal use on a hearth.

Modern plain carbon steels are generally described (e.g. Rollason 1973, 172-3) as mild or low-carbon (below 0.3%C), medium-carbon (0.3-0.5%C), or high-carbon (above 0.5%C). Carbon content may be estimated only very approximately by optical microscopy, particularly when the elemental composition and metallurgical history is unknown (Samuels 1980). Moreover, modern classifications are not strictly applicable to bloomery iron which was usually heterogeneous in carbon and impurity distribution. In the present study, although approximate carbon content is described in relative terms of low, medium and high in the ranges given above, carburization levels are distinguished technologically in terms similar to a scheme devised by Pleiner (Pleiner 1980, 188, tables 11.1-11.4; 1982, Abb. 8).

Group A: Purely ferritic or of low-carbon content (below *c.* 0.3%C); the carbon composition within which effective quench-hardening does not occur

Group B: Unevenly carburized, predominantly comprising areas of medium- or high-carbon content, which are hardenable by quenching, but also containing carbon-free or low-carbon areas which may result in soft areas at working edges

Group C: Medium- and high-carbon content (0.3%C and above) - steels hardenable by quenching to produce relatively uniform structure and hardness.

Groups A, B, and C correspond respectively to Pleiner's groups O, Q, and A, whereas his category Oa is indicated in Tables 4:1, 4:2a, and 4:6, and Figure 4:5, as surface carburization.

Metallurgical terms applied in the present study are defined in the glossary preceding the catalogue in Appendix B (pp. 405-6).

4.2. Selection of ore and bloom

4.2.1. Primary carburization, and impurity content in blooms

Bloomery iron, the product of early smelting processes, is heterogeneous in composition, containing appreciable slag inclusions, sometimes carbon, and significant quantities of impurities (Tylecote 1986;

McDonnell 1988a). Carbon, and impurities such as phosphorus and arsenic, are capable of hardening iron.

Phosphorus is present in most British ores, particularly clay ironstone (Tylecote 1986, 124-7, tables 67-8), and has frequently been detected at high levels in early artifacts (Tylecote and Gilmour 1986, 9, fig. 4, table 2). It is from the ore, and to a lesser extent possibly also from the fuel and furnace linings, that phosphorus arises in the final bloom and slag (Tylecote *et al.* 1971, 361; Hedges and Salter 1973, 172-3).

Arsenic is also relatively common in British ores and in early iron artifacts (Tylecote and Thomsen 1973, table 1; Hedges and Salter 1979, 174, table 4; Tylecote and Gilmour 1986, 5; Crew and Salter 1989, table 4).

Experimental reconstructions of early smelting operations have produced blooms heterogeneous in carbon and impurities (phosphorus and/or arsenic), blooms high in carbon, and some cast irons (Tylecote *et al.* 1971; Clough 1984; 1986; Crew and Salter 1989). These experiments have demonstrated that carbon may be introduced into the bloom without undue difficulty by varying the operational parameters of furnaces (e.g. Tylecote *et al.* 1971, 349, 362, fig. 19, table VII).

Carburization arising through smelting, 'primary carburization', seems to be favoured principally by increasing the fuel to ore ratio, and a reduction in the air blast towards the end of the smelt. Other factors may contribute, such as fine division of the ore, low silica content, and the presence of manganese in the ore. The reconstructions suggest that carburized iron is more readily produced than plain iron, and that if furnaces are operated to yield carburized iron, the yield is increased (i.e. less iron in the slag), but the efficiency of the smelt is reduced (Tylecote *et al.* 1971, 352, 362).

While experiments are useful in understanding the smelting processes, the composition of the final bloom depends not only on the chemical composition and pH of the ore and waste gangue materials, but also on the operational parameters, of which there is little surviving evidence. Post-deposition effects have damaged the superstructures of many Iron Age furnaces, though reassessment of furnace remains in the light of recent research suggests that many of the formerly alleged bowl furnaces were more sophisticated.

Furnaces such as those at Kestor and West Brandon are now considered to have had low shafts, variants now often referred to as low-shaft 'bowl' furnaces (Tylecote 1986, 133, fig. 76). The true shaft furnace became increasingly common from the first century BC (Tylecote 1986, 133-41). Slag tapping facilities are also known on Iron Age furnaces, for example at Broadfield in Sussex, where variants date to the first century BC (Gibson-Hill 1980). Indirect evidence, derived from morphological features of slag, suggests that earlier furnaces were tapped, for example at Castle Yard, Farthingstone, where tapped slag was found in the core of the fifth century BC rampart (McDonnell in Knight 1988, 37-9).

It seems probable that some types of furnaces were able to produce carburized blooms more readily than others, and the variations of furnace types in the Iron Age may in part reflect the choice between a high yield but less efficient process, and a low yield tappable process which enabled greater productivity (Tylecote 1986, 167). The high yield blooms seem more likely to have been carburized (Tylecote *et al.* 1971; Clough 1986), a quality perhaps sought after for some categories of artifacts such as tools.

Only a few possible Iron Age bloom fragments are known (p. 15), two of which have been examined by metallography. One from Danebury (Sellwood 1984, 371, fig. 7.26) comprises plain ferritic iron (Ehrenreich 1985, 209, D30b), as also do two fragments of bloom(s) from Little Waltham, Essex (Tylecote in Drury 1978, 32, 115, pl. XI).

The low number of well-carburized artifacts has led Tylecote to suggest that carburization of blooms was accidental, and that carbon was normally introduced into artifacts later by secondary (surface) carburization (Tylecote (1986, 144).

4.2.2. Selection for carbon

Table 4:1 shows the levels of carburization in the metalworking tools.

All but one of the metalworking tools (No. 54), revealed some carbon in the metal, though in 34% of the tools, the carburization was low and often non-uniformly distributed (Group A). Thirty-one (66%) tools (Groups B and C) attained at least a medium-carbon content in the area examined, which includes twenty-eight (68%) of the edge tools. Samples from six tools comprised relatively uniform steel of greater than 0.6% carbon.

The hammers and chisels had noticeably higher carbon levels than the other tools. The figures are rather inconclusive for some categories of tools; the hearth tools, for example, where there is little value in using steel, were also found to be carburized.

It is worth noting that all of the pokers examined and six of the eight chisels are from the same site (Hunsbury). The high carbon levels in these tools may therefore reflect ore source and smelting technique. On the other hand, the hammers are from six sites from geographically different areas of England.

For reasons discussed later (Section 4.3.1), the carbon in all of the tools examined is likely to have derived from the blooms. In general, the tools have higher carbon levels than other categories of Iron Age artifacts (Table 2:1 and Section 4.6.1), which suggests that the tools were made from blooms (or portions of blooms) selected for their enhanced carbon content. Nevertheless, there appears to have been little selection of evenly, well-carburized blooms for any category of tool, and this may reflect compositional variations in the ore, and difficulties in maintaining smelting conditions.

Table 4:1 Carbon content in individual metalworking tool categories

	Total of tools	A < c. 0.3% C	B uneven C	C > c. 0.3% C	B + C %	Piled	Surface carburized
Pokers	6	3	2	1	50	2	0
Anvils + swages	3	2	0	1	33	0	0
Hammers[α]	14	2	5	7	85	9	0
Chisels and sets	8	2	4	2	75	5	3?
Files[β]	13	5	6	2	61	2	0
Fine tools	3	2	0	1	33	0	0
Total: edge tools	41	13	15	13	68	16	3?
Total: all tools	47	16	17	14	66	18	3?

α Details given in Table 3:3
β Details given in Table 3:7
A Ferrite and/or low-carbon iron (below c. 0.3%C)
B Unevenly carburized: medium- and/or high-carbon steel, but with low-carbon soft areas
C Hardenable steel: medium- and/or high-carbon (over c. 0.3%C)

4.2.3. Phosphoric iron

At ambient temperatures, phosphoric iron is brittle ('cold-short') as a result of the phosphorus segregating to grain boundaries during forging (Hopkins and Tipler 1958, 229-30, 235-6; McDonnell 1988a, 288-9).

Ehrenreich has demonstrated significant levels of phosphorus in Iron Age ploughshares, currency bars, and sickles. He suggests that by the late Iron Age, phosphoric iron ores were employed and that for some categories of products, there was a possible intentional use of phosphoric irons for their hardness (Ehrenreich 1985, 67-71, 77-83).

Phosphorus was absent in the one purely ferritic tool No. 54 (S8/S9), though present in some carburized phosphoric tools (e.g. Nos 71 and 142). Phosphorus was not routinely analysed in the present study, but it seems likely to have been present in a significant proportion of the tools (on the basis of hardness, Neumann lines, and 'ghosting'). Concentrations of phosphorus and other elements are given by Ehrenreich (1985, 207-16) for those samples which he originally sampled and analysed. A hot punch (No. 167) and a cold punch (No. 199) examined by Tylecote also probably contain significant levels of phosphorus (Tylecote 1975, 7, nos 824 and 834).

Whether the presence of phosphorus in an artifact represents the deliberate use of phosphoric iron for its hardness is unclear. For example, hammer No. 71 comprised largely phosphoric iron (though some very low-carbon regions were present) and the tool had been quenched. Pleiner has also noticed the contradiction that artifacts low in carbon were occasionally quenched, and suggests that smiths may have been accustomed to heat-treating, but sometimes misjudged the quality of the metal (Pleiner 1980, 405).

It seems unlikely that phosphoric irons would have been deliberately selected for tools, in particular those intended for striking, to be struck, or for cutting, and thus poor selection of metal is indicated in a few tools.

4.2.4. Bloom and metal preparation (slag inclusions)

The slag and other inclusions in an artifact depend on the initial concentration in the bloom, the degree of bloom preparation and smithing to consolidate and to 'clean' the bloom, iron oxide scale and any flux incorporated during forging.

Slag inclusions in the samples from the metalworking tools were frequently present in only small quantities. Often, these were particulate and well-rounded, and any stringers present were usually well-broken, suggesting that considerable bloom preparation and forging had taken place. Where there was a higher proportion of inclusions, or larger stringers were present, this normally occurred in ferritic or low-carbon regions. Homogeneous high-carbon regions were invariably inclusion-free. Furthermore, samples with a carbon gradation but predominantly of high-carbon content were invariably 'clean' at the high-carbon region, whereas any concentration of inclusions was usually present in regions of low-carbon (e.g. S28, S37, S45).

Smelting reconstructions suggest that rich ores (e.g. haematites) produce blooms which are relatively slag-free (Clough 1986, 35), and that ores low in silica produce the most free-running slags of minimum fayalite content (Tylecote *et al.* 1971, 362; Tylecote 1986, 167). Furthermore, it has been found that in reconstructions to produce carburized blooms, slag is able to separate more easily, and that the metal in the bloom less contaminated with slag (Tylecote 1986, 167). The uneven partitioning of the inclusions which was noted in the samples may therefore reflect the smelting of ores heterogeneous in iron and gangue composition, and possibly also the smelting of blooms to deliberately enhance the carbon content. However, at present the experimental evidence is limited, and there is no information regarding the removal of slag from carburized blooms during refinement (but cf. Crew and Salter 1989).

Similar variations in inclusion concentrations between high- and low-carbon regions in artifacts of later date have been observed by McDonnell who considers that they may reflect different working properties of the metal rather than characteristics of smelting (J.G. McDonnell pers. comm.). He suggests that ferritic irons would require higher temperatures and more fluxing for welding during piling, and being more ductile than steels, may encourage the slag and other inclusions to concentrate in the less carburized regions.

4.3. Forging

The principal metallurgical effects of hot-forging are the redistribution of impurities and inclusions, oxidation at the metal surface, and alterations in microstructure. The properties of iron may be altered by the solid state changes which occur due to temperature changes, by mechanical effects of hammering at elevated temperatures, and by increasing the carbon content or welding in steels of enhanced composition (Chapter 1.3.3). This Section examines the evidence of alteration in properties in the metalworking tools due to hot mechanical work, whereas effects due to cold-work, secondary carburization, and quenching are discussed in Section 4.4.

4.3.1. Pile-forging and welding

Evidence of welding may suggest the means of construction and the degree and efficiency of pile-forging, though need not suggest any particular technological achievement unless the welding-in of steel components (or the piling of surface-carburized strips) is indicated. The principal metallurgical effects of hot-forging which are relevant to the interpretation of the metalworking tools are:

(1) Mechanical effects of hot-work (i.e. without welding)

(2) Changes due to pile-forging and welding.

(1) Mechanical effects of hot-work

The heterogeneously distributed regions of carbon which occur in a bloom are later either homogenised during forging or are concentrated into zones if certain impurities such as phosphorus are present (McDonnell 1988a, 289). Carbon and phosphorus are mutually exclusive; phosphorus inhibits the diffusion of carbon and causes carbon to segregate into zones or to grain-boundaries (Stead 1918; Hopkins and Tipler 1958, 229-30, 235-6). In iron-carbon-phosphorus alloys, the phosphorus and carbon therefore segregate into zones during forging (visible in a two-dimensional metallographic section as a banded structure).

Banded carburized structures may also arise from the piling of surface carburized iron strips (Tylecote 1986, 145), and the effects are not necessarily distinguishable from segregation effects (Pleiner 1973).

(2) Pile-forging (cf. Fig. 1:3)

The main visible metallurgical effects of welding (e.g. in during pile-forging are:

(a) Segregation of carbon and phosphorus: piling may result in pronounced and extensive banding.

(b) Decarburization: carbon depletion at the surface of the iron, later becoming incorporated into a weld.

(c) Inclusions of iron scale and any fluxes used (p. 22 and p. 25).

(d) Enrichment of arsenic and other impurities: elements which form substitutional lattice structures, such as arsenic (Tylecote and Thomsen 1973), nickel, cobalt and copper (Tylecote 1990), may become enriched at weld lines due to migration of the impurity away from the metal surface when heated, forming a sub-scale layer. During welding, the depleted layer may be lost as scale and the enriched layer is then welded to another iron surface (Tylecote and Thomsen 1973). Pronounced arsenic enrichment is often visible in metallographic sections as light-etching lines ('white lines') and their presence is invariably indicative that welding has taken place (Tylecote and Thomsen 1973; Tylecote and Gilmour 1986, 5).

Six samples were analysed for elemental composition in segregation lines. High arsenic levels were detected in No. 62 (S13), No. 66 (S18), No. 67 (S20), and No. 76 (S31). Phosphorus was detected in No. 71 (S24 and S25) and No. 142 (S55).

The samples from one face of each of hammers No. 71 (S25) and No. 76 (S31) revealed the most dramatic effects of elemental and carbon segregation, whereas in other tools, for example hammers, No. 66 (S17/S18) and No. 67 (S20), the carbon was relatively even in distribution but the microstructures were appreciably banded.

CONCLUSIONS

1) In the metalworking tools examined, evidence of welding (i.e. during normal forging and piling of iron) occurred in eighteen tools (Table 4:1), though this is a conservative number based on the samples which exhibited unambiguous evidence.

2) There was no evidence to suggest that any of the tools had been made by piling strips of surface carburized iron. However, heating, and hot-forging even for short periods of work, may obscure evidence of welding and use of carburized components (Pleiner 1973, 21), and thus the possibility (although unlikely) cannot be discounted. The simpler explanation of segregation effects due to carbon and phosphorus is preferred.

3) Only two tools, No. 62 (S13) and No. 76, (S30) revealed evidence of

decarburization at a weld line which, in conjunction with the general lack of associated inclusions, suggests that piling was normally cleanly and efficiently carried out.

4) Inclusions associated with the weld lines were generally extremely small - their presence was often betrayed by light-etching lines. Sometimes, the microstructure was continuous beneath 'white lines' suggesting rapid and efficient welding (e.g. S20, S41, S57).
5) None of the tools revealed evidence of a welded-on steel edge, though two tools seem to have been made with welded-in components. Cold set or wedge No. 113 (S39) may have had a high-carbon strip sandwiched between low-carbon components. This tool is discussed by Ehrenreich (Salter and Ehrenreich 1984, 157, fig. 10.9A; Ehrenreich 1985, 63, fig. 3.9). Chisel No. 100 (S44) has a complex structure at the cutting edge and may possibly have had outer strips welded on to a medium-carbon core. However, the medium-carbon region occurs well away from the cutting edge and thus it seems unlikely that enhancement of properties was intended. Possibly this structure results from the reforming the cutting edge.

4.3.2. Temperatures attained

The temperatures attained during forging of the metalworking tools (cf. Figure 1:1) could not always be determined owing to effects of subsequent heatings which had obliterated the metallurgical evidence of prior treatment (cf. Pleiner 1973). In addition, the visible features in steels which have been reheated after air-cooling or quenching may be very similar, and difficult to interpret since prior work may effect the rate of spheroidisation (Desch 1923; Samuels 1980, 228-9). Therefore, likely temperatures attained during forging and heat-treatments are generally expressed in the present study in terms of phase (Figure 1:4) or degree of heating, rather than according temperature in °C.

Twenty-four of the tools were air-cooled from the fully or partly austenitized condition (Table 4:2); a further tool, hammer No. 66, was air-cooled at one face but quenched at the other (Table 3:3).

Grain growth from probable extended heating at elevated temperatures (Fig. 1:2) was visible in a few of the samples (e.g. S27, S28, S55). Recrystallisation of grains, indicating structure prior to

A. Carbon content v. final heating cycle in the 47 tools

	A < c. 0.3%C	B uneven C	C > c. 0.3%C	Total
total	16	17	14	47
surface carburized	0	2?	1?	3?
air-cooled	10	7	7	24
quenched	5	9	4	18
spheroidized microstructure	1	1	3	5
reheated	3	1	6	10

A Ferrite and/or low-carbon iron (below c. 0.3%C)

B Unevenly carburized: medium- and/or high-carbon steel, but with low-carbon soft areas

C Hardenable steel: medium- and/or high-carbon (over c. 0.3%C)

B. Final heating cycles in the individual categories of tools

	Total of tools	Air-cooled	Quenched	Spheroidized microstructure	Reheated
pokers	6	6	0	0	2?
anvils + swages	3	2	0	1	1
hammers*	14	2	10	2	3
sets + chisels	8	7	1	0	0
files	13	4	7	2	2
fine tools	3	3?	0	0	2?
total	47	24	18	5	10?

* See Table 3:3 for details (S17, air-cooled, excluded for these figures)

Table 4:2 Carbon content and final heating cycles in the metalworking tools final heating, was visible in S6, S7, S33 and S34.

A number of the tools had been reheated subsequent to forging, and possibly after heat treatments. It is possible that reheating may have been accidental, perhaps during use on a hearth, or that some tools were found to be unduly brittle in their quenched condition, and had been reheated (annealed) to soften the steel.

The samples from five tools, No. 47 (S7), No. 63 (S16), No. 77 (S33/S34), No. 142 (S55), and No. 159 (S59), comprised spheroidized carbides, and the former microstructure of these tools could not be interpreted (Table 4:2b, fourth and final columns). Where the cementite was visible as very small and discrete granules, this suggested that the former microstructure may have been relatively fine. Five other tools had been reheated less severely resulting in coarsened microstructure (Table 4:2b, final column). Another tool, hammer No. 61 (S11) revealed martensite and bainite of very degraded appearance and low hardness, and this may have resulted from reheating to about 600°C or 700°C for only a few minutes.

4.3.3. Grain refinement

A few of the samples comprised evenly distributed small grains suggesting that the tools had been forged in such a manner to refine the grain size and strengthen the iron (cf. Fig. 1:2), for example No. 94 (S42), No. 147 (S56), and No. 220 (S62).

4.4. Hardening techniques

Iron may be hardened by alloying, working, and heat treatments (Chapter 1.3.3).

4.4.1. Primary carburization

As the concentration of carbon is increased in a steel, the strength and hardness increase (Fig. 1:5a), due to the carbon forming an interstitial solid solution in the alpha and gamma phases of iron (p. 23). The hardening effects of carbon are considerably greater than with elements such as phosphorus and arsenic which form substitutional solid solutions (Samuels 1988, 324-32).

The carburization levels in the metalworking tools are discussed above (p. 180-1) where it is noted that 68% of the edge tools examined comprise at least 0.3% carbon.

4.4.2. Secondary carburization

Carbon may be absorbed into the surface of austenitic iron by heating it with finely powdered charcoal or other carbonaceous material in a sufficiently reducing atmosphere (Shaw Scott 1907; Tylecote 1986, 144-5). At the metal surface, carbon monoxide breaks down to atomic carbon, which reacts with the iron to form cementite. A carbon gradient develops, with the highest carbon in the surface layer, but the rate of diffusion is very slow - in the order of 1-2mm in two hours at 1000°C (Tylecote and Gilmour 1986, 15, fig. 5, tables 4-5). Although this technique implies special conditions for the carbon to enter the iron structure, there is a possibility that carburization may occur if iron is buried beneath the charcoal in a hearth (Tylecote 1986, 173).

Until very recently, surface carburization was used in particular for files as these require only a thin surface layer of steel (cf. Rees 1819), and a less brittle core is preferred (Carr 1969).

Samples from three chisels revealed traces of possible surface carburization: Nos 94, 100, and 108. None had been quenched. In all three samples, the carburization was limited to one or more short regions of metal at severely corroded edges of the samples. There is some uncertainty whether these regions of enhanced carbon are the remains of surface carburization, or heterogeneity arising from the blooms.

4.4.3. Working

(a) Cold-working

Impurities such as phosphorus and arsenic (Section 4.2.1) confer hardness and strength which may be enhanced by cold-work (Tylecote and Gilmour 1986, 7-8, fig. 4, tables 1-3).

In none of the tools examined was there evidence of intentional cold-work to harden the metal prior to use. Samples from five tools revealed evidence of work-hardening which was presumably through use: ?bench anvil No. 54, hammers Nos 71, 66, and 76, and ?cold set No. 113. Poker No. 17 may have been reformed by cold-work.

(b) Hot-working

Hot-forging of iron under certain conditions (p. 19) refines the grain size and increases hardness, toughness, and strength (Andrews 1977, 106), though has a greater effect on the latter two properties (Chapter 1.3.3). See above, Section 4.3.3.

4.4.4. Quenching

A steel may be appreciably hardened by cooling it very rapidly from the austenitized condition (Fig. 1:5a). The structure which develops depends principally on the rate of cooling, the carbon content, and the presence of other elements (Samuels 1980).

In Chapter 1.3.3 it was noted that the carbon in austenite is held in the face-centred cubic crystal structure, but during cooling, the crystal structure changes to the body-centred cubic form and is then unable to retain any significant amount of carbon. The nature of the transformation products which austenite yields on cooling is determined by the ability of the carbon to diffuse during crystal changes, and coherency between the interfaces of the microstructural phases (Porter and Easterling 1981).

Severe quenching results in diffusionless transformation of the carbon to form laths or plates of hard martensite. If the quench is less drastic, or interrupted before martensite forms, there is time for some carbon diffusion to occur, and constituents such as bainite ('lower bainite' and 'upper bainite') and nodular pearlite may form. If the cooling rate is sufficiently slow, the carbon diffuses to form pearlite, or sometimes grain-boundary carbide particularly in very low-carbon irons (Samuels 1980).

The concentration of carbon and other elements in solid solution in the austenite alter the temperatures at which transformations proceed and finish, and affect the relative proportions of the products (Bain and Paxton 1966). Localised variations in impurities may have a marked effect, which in conjunction with non-uniform carbon distribution, may then result in a variety of transformation products within a small volume of metal.

The cooling rate during quenching depends on the nature of the cooling medium, the degree of agitation, and the cross-section of the item (Atkins 1977). Items of very narrow section may be cooled sufficiently rapidly in air for martensite to form.

For a steel of known composition and prior metallurgical history, the transformation products which are likely to be formed on cooling may be predicted by reference to time-temperature-transformation (TTT) diagrams and continuous cooling transformation (CCT) diagrams (e.g. Samuels 1980, figs C4-C8 and C10-C12). Such diagrams are seldom if ever appropriate for the interpretation of archaeological samples, although those which incorporate data for cooling rate in terms of cross-section may sometimes be useful (e.g. Atkins 1977). Nevertheless, all of these diagrams have been calculated from modern industrial steels under equilibrium conditions; impurities displace the curves to the right with respect to the temperature axis. For archaeological samples it is often difficult to interpret composition, constituents, and rate of cooling, since equilibrium conditions are not achieved (cf. Lang 1988).

Samples from eighteen of the metalworking tools revealed microstructures typical of quenching or extremely rapid cooling (Table 4:2). Ten of the 14 hammers had been quenched at one face at least (Tables 3:3 and 4:3), 7 of the 13 files (Tables 3:7 and 4:4), and a possible cold-set (No. 113).

Table 4:3 Hammers: final heating cycles

	Total no. of faces	Examined at 1 face only	Examined at 2 faces FACE 1	Examined at 2 faces FACE 2	Examined at the eye
Total	21	7	7	7	4
Air-cooled	3	2	1	0	3
Quenched	15	4	5	6	1
Spheroidized microstructure	3	1	1	1	0
Reheated	4	2	1	1	0

Table 4:4 Files: carbon content and final heating cycles

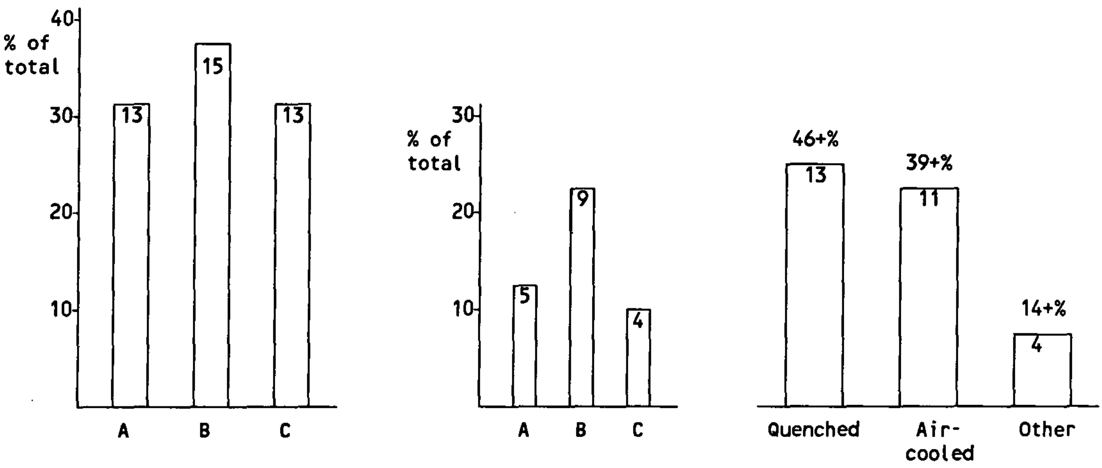
	A below c. 0.3%C	B uneven C	C above c. 0.3%C	Total
Total	5	6	2	13
Air-cooled	2	1	1	4
Quenched	3	4	0	7
Spheroidized microstructure	0	1	1	2
Reheated	0	1	1	2

Another tool (S67), a tanged implement (see above, Table 3.10, and p. 170), and not counted in the above eighteen, is of sufficiently small cross-section for the microstructure to have developed as a result of air-cooling.

Excluding hearth tools, which would not in any case be expected to be hardened, 44% of the (edge) metalworking tools were quenched. In terms of hardenable steels (Table 4:1, groups B and C), 13 of the 18 quenched tools comprise at least 0.3% carbon, equivalent to 46% of the edge metalworking tools. Figure 4:2 shows the percentage edge tools which were quenched, in relation to their carbon content.

Although a few of the quenched samples were predominantly martensitic, for example S12 (No. 62), S19 (No. 66), and S36 (No. 86), none was totally free of other transformation products. Invariably, nodular pearlite and/or feathery grain-boundary ferrite (in most cases probably upper bainite) was present in very small amounts, which in these particular samples tended to suggest heterogeneity in composition. Bainite was present in massive form in S28 and S29 (No. 73), and its association with martensite suggests a relatively severe quench.

Figure 4:2 Frequency of carburization and quenching in the 41 edge tools (%)



a. % tools in each carburization group

b. % quenched tools in each carburization group

c. % hardenable steels which are quenched (Total 28)

A Below c. 0.3%C
B Heterogeneously carburized
C Above c. 0.3%C

All but four of the quenched tools had some low-carbon areas in their structure present either as carbon gradients or localised areas (group B tools), or throughout the metal samples (group A tools).

Low-carbon quenched samples

It has not been possible to identify with certainty a number of the transformation products in the low-carbon quenched irons. These are discussed below since their interpretations affect the number of quenched tools.

The samples which comprised low or uneven carbon composition frequently revealed acicular light-etching constituents which were irresolvable under light microscopy, and sometimes only partly resolvable under scanning electron microscopy (e.g. S24, S30, S54, S56, S57). It is possible in these tools quenching occurred from the partly austenitized or partly transformed condition (i.e. from within the A_1-A_3 range), the austenite developing along crystallographic planes and later transforming to acicular martensite. Under these conditions ('dual-phase' steels), the localised carbon in the martensite may reach relatively high concentrations, for example 0.6%, though the overall carbon content may be low (N. Ridley pers. comm.). The localised areas of high carbon may enable transformation of the austenite to martensite (and other constituents) despite TTT curves indicating otherwise (contra Rollason 1973, 185; Lang 1988, 211). It may be relevant that quenched low-carbon steels (below 0.25% carbon) are noted for their toughness and strength (Davenport 1979; Samuels 1988, 409-410).

An alternative explanation for some of the acicular constituents is that they may be bainite growths which had developed during quenching from the A_1-A_3 range (cf. Bain and Paxton 1966, fig. 211; Hehemann 1970, fig. 21), or some may be transitional forms of bainite and pearlite (cf. Porter and Easterling 1981, 334-7).

Another transformation product commonly observed in low-carbon regions was darker-etching than martensite, sometimes feathery at the edges, and invariably associated with martensite (e.g. S21, S30-S32, S48, S51, S52, S54, S56). This is similar to a constituent described by Samuels as 'a structure that is a high-temperature transformation product nucleated at the ferrite-austenite interface during cooling' (Samuels 1980, 68) in steels austenitized in the A_1-A_3 temperature range. On the basis of SEM, this constituent was interpreted in S21, S30, S54, and S56 to be 'pearlitic', but a constituent resulting from rapid cooling rather than the lamellar form of pearlite which forms during air-cooling (cf. Samuels 1980, 68, fig. 13-14; Bain and Paxton 1962, 89-93, figs 69-74).

Although uncertainty remains with the identification (and thus terminology) of a number of the austenite transformation products in low-carbon irons, they were nevertheless formed as a result of quenching since they occur also in samples which were predominantly martensitic at high-carbon areas (e.g. S13, S49, S54).

Quenching technique

The differences in microstructure within the individual tools may be attributed to heterogeneity in carbon and elemental composition. It seems likely that some tools were incompletely quenched, possibly due to the following reasons:

(1) Insufficient heating (incomplete austenitization)
(2) Delayed quench (some transformation of austenite to ferrite in hypo-eutectoid steels)
(3) Slack-quenching (less severe cooling rate, for example in oil, or due to lack of agitation during quenching)
(4) Brief quench (early removal from the quench bath)
(5) Selective quench (only a portion of the tool immersed, leading to auto-tempering of adjacent martensite)
(6) Interrupted quench (temporary removal of the item before completely cooled).

The tools which were quenched from the partly austenitic condition (e.g. Nos 56, 71, 76) may have been the result of heating for an insufficient time, perhaps because the smiths misjudged the temperature (cf. Fig. 1:4). 'Slack-quenching' is sometimes used today to prevent cracking through volume changes which may arise in martensite (Samuels 1988, 419).

'Interrupted quenching' may possibly have occurred with some files since these are well known to bend during quenching due to internal stresses, particularly if the carbon composition or the cross-section is non-uniform (J. Nicholson per. comm.). Medieval sources suggest that files should be straightened in the quench bath before fully cooled (Smith 1968, 61, after Jousse 1627). This implies straightening the file before martensite is formed, a manipulation which may not have been very easy to perform in a quenching bath. It seems possible that 'stubborn' files may have been removed briefly from the quench bath and straightened with a mallet. Later sources suggest various methods of plunging files of different cross-section into the quench bath to overcome these problems (e.g. Rees 1819). File No. 148 (which was quenched) is bent sideways, possibly a result of such problems.

4.4.5. Tempering

Martensite may be tempered by low-temperature heating to modify the hardness, reduce brittleness, and increase toughness (Samuels 1988).

Three tools revealed possible evidence of tempering (Nos 113, 126, 132). In addition, No. 61 revealed very degrade martensite and bainite suggesting reheating to moderate temperature (Section 4.3.2). However, for the reasons given below, these four tools need not necessarily have been deliberately heat treated to modify properties. Tempering effects may occur through:

(1) Auto-tempering: for example as a result of incomplete quenching due to inadequate agitation, or by back-flow of heat from an unquenched part of a tool

(2) Accidentally heated on a hearth (cf. above p. 186-8)

(3) Heat transfer through use, or mis-use.

The effects of tempering at low temperatures may be detected only indirectly by optical microscopy, by assessment of etching rate on metal samples of known composition and history (Samuels 1980, 373-8). A fast etching rate, although generally indicative of tempering, may be suppressed by prior cold-work, and decreases in hardness may be effected by elemental and phase composition. Low hardness and a fast etching rate cannot therefore be taken as unequivocal features of deliberate tempering. Furthermore, it is possible that some of the tools had been heated during conservation treatment, for example by boiling, or during drying in an oven (cf. Tylecote and Black 1980).

In conclusion, it is not possible to say that any of the tools had been deliberately tempered to modify hardness or brittleness. However, a few of the tools may have been quenched in such a manner (e.g. slack-quenched) that tempering effects occurred, and it is possible that the enhanced benefits may have been realised by the Iron Age metalworkers.

4.5. <u>Technological trends</u>

4.5.1. Geographic and chronological trends

The metalworking tools sampled, all from England, are from six hill-forts, seven settlements, a burial, and a 'hoard' recovered away from settlement. Geographically the spread is between North Humberside and Dorset, and chronologically between the fifth century BC and the first century AD. Geographic distribution is shown in Table 4:5 and Figure 4:3, and probably dates of deposition in Table 4:5.

Few of the tools are closely datable, and tools from individual sites are not, or are not necessarily, from contemporary settlement (Chapter 5). This allows little technological comparison of the tools between assemblages or between sites, nor for any one tool category. In addition to the single tool examined in this study from Gussage All Saints (No. 126), six others have been examined by Tylecote (1975); the results are summarised by phase of settlement in Table 5:2.

The principal findings are:

(1) High carbon contents, and in a variety of artifacts types (Section 4.6.*I*, below), occur at Hunsbury and at Gussage All Saints.

(2) The earliest incidence of quenching occurs in hammers Nos 62 and 71, possibly 4th century BC; hammers Nos 61 and 72 are also potentially early.

(3) Quenching occurs in metalworking tools from 11 of the 15 assemblages. (This may be expressed that quenching occurs any group where at least two or more hammers or fine-cut files are present!)

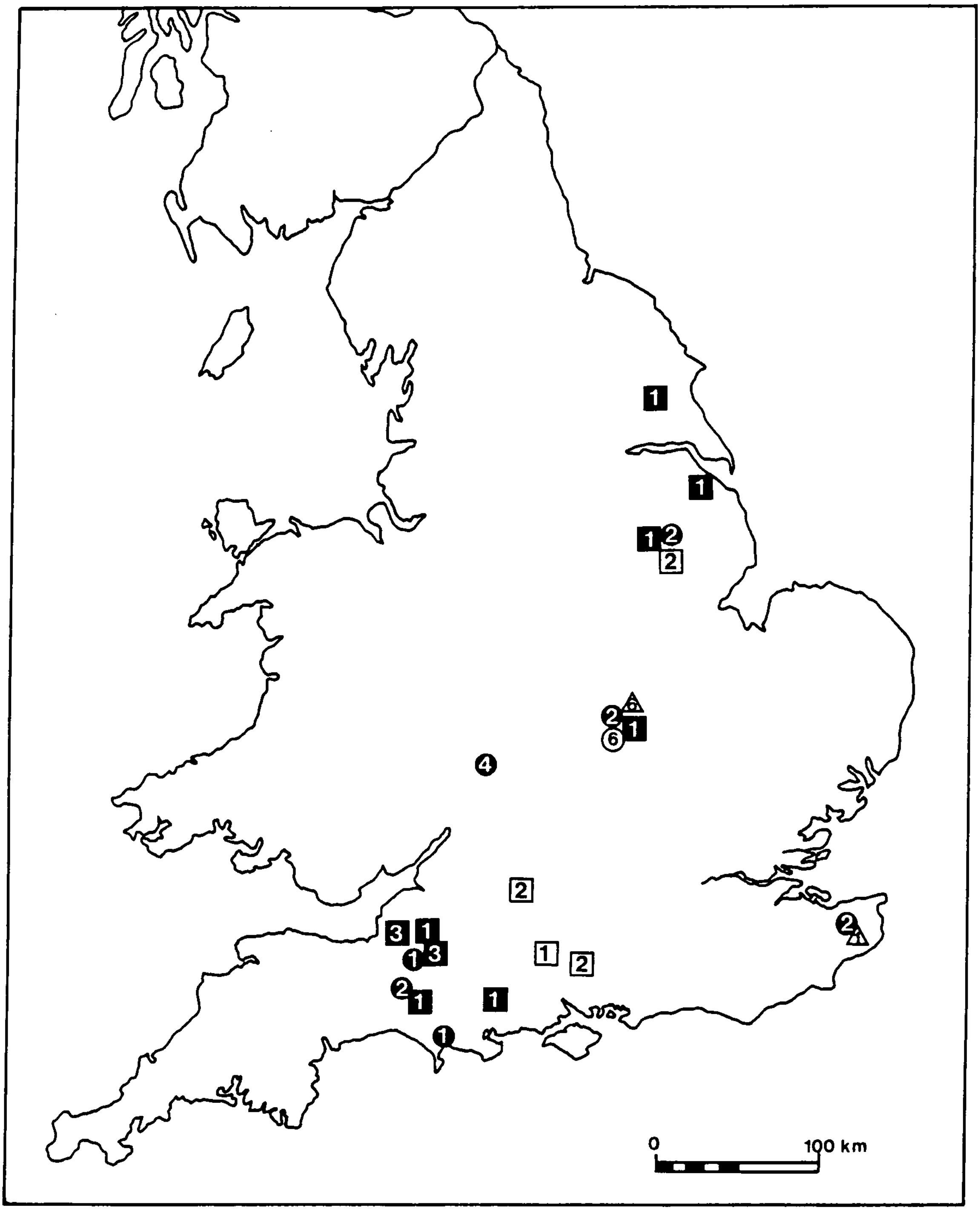
(4) Certain typologically similar hammers, those which are probably specialised hammers (for raising, sinking, or planishing), show the highest incidence of quenching. These occur between Lincolnshire and Somerset.

(5) Of the sampled files, only the finely-cut are quenched (7 of 11), including 6 of 8 files from the Somerset 'lake' villages; the seventh is from Dorset. This distribution probably reflects no more than the occurrence of fine-cut files sampled, and in addition, very few coarse- and medium-cut files have been examined.

It is concluded that enhanced carbon content relates to ore source, smelting technique, and in some tools also to technological requirements, and that quenching correlates which functional variation in the tools, there being no real chronological or geographic trends.

Site	Tool	Date of context
HILLFORTS		
Barbury Castle, Wilts	anvil No. 47; ?graver No. 208	?C2nd - C1st BC
Bigbury, Kent	hammers Nos 63 and 68;	?late C1st BC
	chisel No. 95	"
Bredon Hill, Glos	hammer No. 73	end C1st BC
	hammer No. 77	mid/late C1st BC
	hammer No. 86	early/mid C1st AD
	hammer No. 89	early/mid C1st AD
Danebury, Hants	?scriber No. 219	late C5th BC
Ham Hill, Som.	hammers Nos 66 and 76;	?later IA
	file No. 132	"
Hunsbury, Northants	pokers Nos 12, 13, 16, 17, 19 and 25; hammers Nos 61 and 72; chisels Nos 91, 94, 100, 103, 104 and 108; file No. 119	C5th/4th BC - C1st BC/AD "
SETTLEMENTS		
Glastonbury, Som.	hammer No. 84; files Nos 130, 133 and 147	C2nd BC - C1st AD
Gussage All Saints, Dorset	file No. 126	C1st AD
Meare Village East, Som.	file No. 120	C2nd BC - C1st AD
Meare Village West, Som.	files Nos 148, 150 and 159	C3rd BC - C1st AD
Weelsby Avenue, S. Humb.	file No. 122	mid-C1st BC
Wetwang Slack, N. Humb.	file No. 124	later IA - RB
Worthy Down, Hants	?cold set No. 113;	early C2nd BC
	?scriber No. 220	mid-C1st BC - mid-C1st AD
BURIAL		
Whitcombe, Dorset	hammer No. 67	earlier C1st AD
HOARD		
Fiskerton, Lincs	?bench anvil No. 54; top-swage No. 55; hammers Nos 62 and 71; file No. 142	? c. C4th BC

Table 4:5 Geographic and chronological distributions of the metalworking tools examined by metallography



Number of sampled tools indicated within the symbols

- ● Hammer
- ■ File
- △ Chisel
- ○ Poker
- □ Other

Figure 4:3 Map showing the distribution of the metalworking tools examined by metallography

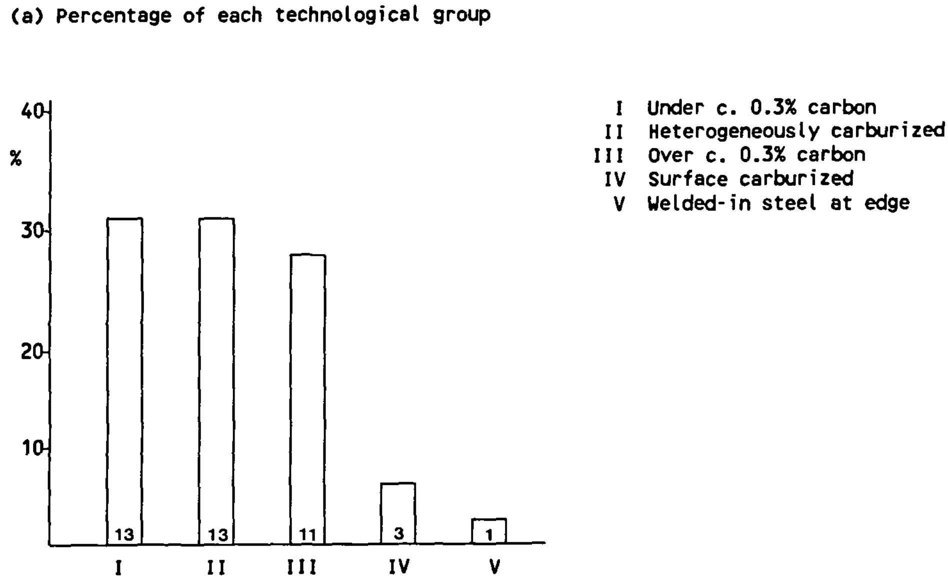
4.5.2. Technological levels in the metalworking tools

The technological level of ferrous edge tools and implements may be assessed from features which suggest enhancement of properties in relation to the function of the artifact. The qualities required of edge tools may include hardness, durability, strength, toughness, and the ability to acquire and maintain the edge (Chapter 1.8). Carbon seems to be the only element in bloomery iron which is capable of strengthening and hardening iron without leading to brittle and damaged edges in tools (cf. McDonnell 1988a, 289). For some types of tools, toughness in the body of the tool may be achieved by incorporating softer iron, or by selective quenching of the working edge. The principal determining features of enhancement of properties (Piaskowski 1961; 1987; Pleiner 1980; 1982) are therefore:

(1) Degree and uniformity of carburization at working edges
(2) Surface carburization at working edges
(3) Folding of the metal so that a more carburized region of metal occurs at the working edge
(4) Piling of surface carburized components to increase carbon
(5) Incorporation of one or more medium- or high-carbon components in such a manner that the steel occurs in the working edge
(6) Cold-work to increase hardness
(7) Heat treatments and hot-forging to modify grain form and structure
(8) Quench-hardening
(9) Deliberate tempering.

In the metalworking tools examined there was no evidence of (3), (4), (6), and (9) above.

Following a scheme devised by Pleiner (1982, Abb. 8 and 10), and used subsequently by Hennig (1986, Abb. 21), the technological groupings of the edge metalworking tools are shown in Figure 4:4. One of the categories used by Pleiner, piling of surface-carburized strips, is not applicable to the tools studied here and is therefore not included. A category used by Hennig, heterogeneously carburized and banded low-carbon irons, <u>is</u> applicable and is therefore shown. (In Pleiner's system, this additional category would fit into the lowest level of technology, below 0.3% carbon.)



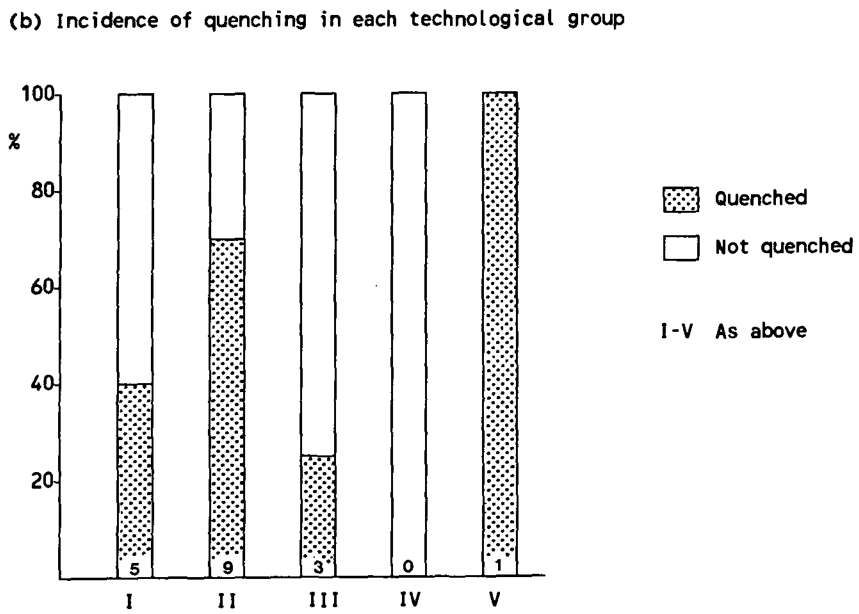


Figure 4:4 Technological groups and incidence of quenching in the 41 edge tools

4.6. <u>Comparison of the metalworking tools with other Iron Age edge tools and ironwork from Britain (from published sources: Table 2:1)</u>

This Section evaluates the metalworking tools in terms of carbon content and technology by comparing the tools with other categories of ironwork from selected assemblages in Britain. The largest assemblages of artifacts which have been examined for <u>metal structure</u> (see p. 67) from individual sites are from Danebury and Gussage All Saints. Individual categories of artifacts which have been studied in any number are currency bars and swords.

4.6.1. Carbon content, cold-work, and quenching

I. <u>Carbon content</u>

(a) From Gussage All Saints, Tylecote has examined 18 ferrous artifacts (Tylecote 1975; Spratling *et al.* 1980, 284-5, table 2) from two metalworking deposits dating to the third to first centuries BC (cf. Fell 1988). These include six metalworking tools (?cold set No. 116, file No. 143, punches Nos 164, 167, 169, 199). Nine of the artifacts reached *c.* 0.3% or higher carbon in the area examined: four of the metalworking tools (Nos 116, 143, 164, 169), a rivet, a bridle-bit link, a possible off-cut, and two unidentified artifacts (Tylecote 1975, 5-7, nos 126, 127, 283, 510, 575, 702, 822, 828, and p.8, no.3).

(b) From Danebury, Salter has examined 16 <u>metallic</u> ferrous artifacts, principally from cp7 (300-100/50 BC) contexts (Salter 1984, 434-6, Mf 13:C4 table 122). Fourteen of the artifacts are edge tools or implements, including two possible metalworking tools (chisel No. 109 and a medium-cut file No. 123). Six tools were found to comprise regions of greater than 0.3% carbon: chisel No. 109, two woodworking chisels, a coarse-cut file, an adze, and a pick (Salter 1984, Mf 13:C4, nos D185/D186, D139, D157/D158, D172, D164, and D169).

(c) Ehrenreich has studied ferrous artifacts from 23 varied assemblages from central and southern England, principally from Danebury and Hunsbury (Ehrenreich 1985; 1986). His study was concerned mainly with elemental composition (see above, p. 67 and p. 80), though some artifacts were assessed also for carbon levels, cold-work, and to some extent for heat treatment. The study includes the 16 artifacts studied by Salter (1984) mentioned above, *(a)*, and 26 metalworking tools (examined now in the present study). Ehrenreich determined that only

51 of 329 (metallic) artifacts had a carbon content of 0.3% or above (equivalent to 15%) and that of these, the chisel-type tools (10 of 15) in particular were high in carbon (Ehrenreich 1985, 62-3, fig. 4.3). Fourteen of the metalworking tools were determined to comprise greater than 0.3% carbon (but cf. S27 in the present study, and Ehrenreich 1985, HYN70b). If from the total number of artifacts determined to contain *c.* 0.3% carbon (51 artifacts), the metalworking tools and the tools examined by Salter are excluded, this should leave only 23 additional artifacts of enhanced carbon content (equivalent to 8% of the remainder, some of which may be edge tools and implements).

(d) Other artifacts which have been found to well-carburized include a tyre from Llyn Cerrig Bach (Cook in Fox 1946, 75-6), and some of the currency bars from Beckford (Hedges and Salter 1979, 165).

Comparing the analyses *(a)* - *(d)* above with the results from the present study, the indications are that certain types of artifacts were not infrequently manufactured from well-carburized iron, principally metalworking tools and woodworking chisels. Moreover, it seems that at some sites, for example Gussage All Saints (Tylecote 1975) and Hunsbury (Ehrenreich 1985), a significant proportion of all categories of artifacts were made from carburized iron.

II. Surface carburization

Surface carburization is rarely reported (corrosion effects often lead to uncertain identifications). Possible examples include three swords - from Whitcombe, Grimthorpe, and Stanwick (Lang 1987, 62, 71-2, nos 10 [also quenched], 14, and 16), and two axeheads from Fiskerton (V. Fell forthcoming).

III. Quenching

Quenching is reported in the following Iron Age artifacts:

(1) Two woodworking chisels from Danebury, one from a cp5 (*c.* 400 BC) context, the other from a cp7 (300-100/50 BC) context (Sellwood 1984, fig. 7.11, no. 2.46, and B. Cunliffe forthcoming); Salter 1984, 435, Mf 13:C4; Salter and Ehrenreich 1984, 156; Ehrenreich 1985, 63).

(2) A first century BC sword from Grimthorpe, North Humberside (Stead 1968, 170, fig. 15; Lang 1987, 71, no. 10).

(3) A knife from a third to first centuries BC context at Winklebury, Hampshire (Smith 1977, 82, fig. 37, 4; Tylecote 1986, 152, fig. 93a).

(4) Two metalworking tools from Gussage All Saints; ?cold set No. 116, and file No. 143 (Tylecote 1975, 5-7, nos 283 and 822; Spratling *et al.* 1980, 284-5; see also Fell 1988). No. 116 is from a first century BC context; No. 143 is from a third to first centuries BC context.

(5) A possible cold set (No. 113, S39), or wedge, from a second century BC context at Worthy Down (Salter and Ehrenreich 1984, 157, fig. 10.9, A; Ehrenreich 1985, 63, fig. 3.9).

Thus, seven Iron Age artifacts have been reported to be quenched: two woodworking chisels, a sword, a knife, and three possible metalworking tools. Including analyses from the present study, the total number of Iron Age artifacts determined so far to have been quenched is twenty-four; ten hammers, eight fine-cut files, two possible cold sets, two woodworking chisels, a sword and a knife.

Of the 49 probable and possible edge metalworking tools which have been analysed (in the present study and those listed above), twenty are quenched (41%). In other categories of artifacts, the incidence of quenching appears in general to be lower, for example two of seven woodworking chisels (Table 4:6, below), one of *c.* nineteen swords, and one of *c.* 30 knives (cf. Table 2:1).

IV. Cold work

It is possible that cold-working, whether to deliberately harden, or to reform an edge, was not uncommonly applied to weapon and implement blades. For example, a knife from Gussage All Saints (Tylecote 1975, 5, no. 127) is cold-worked, and also a first century BC sword from Orton Meadows, Cambridgeshire (Lang 1987, 71). Ehrenreich notes evidence of cold-work in 24 varied artifacts and concludes that they were either work-hardened in use or had not been annealed during manufacture (Ehrenreich 1985, 61-2, fig. 4.2).

4.6.2. Comparison of technological properties in the edge metalworking tools and edge tools for other crafts

Table 4:6 summarises the technology applied to the metalworking tools and selected categories of other tools for those where sufficient numbers have been analysed to enable meaningful comparisons to be

Table 4:6 Summary of technology of selected categories of Iron Age edge tools from England and Wales

Artifact	Total	<0.3%C (A)	>0.3%C (B+C)	Surface carburized	Weld[α]	Air cooled[β]	Quenched[β]	Source
hammers	14	2	12	0	0	2	10	Table 3:3
hot chisels/sets	7	2	5	2?	0	7	0	S38, S40-S45
?cold sets/wedge	3	0	3	0	1?	1?	2	S39; Table 2:1/12 (D186), 2:1/17 (283)
hot punches*	2	1	1	0	0	2	0	Table 2:1/17 (510, 834). See also Table 5:2
cold punches*	2	1	1	0	0	2	0	Table 2:1/17 (575, 824). See also Table 5:2
fine-cut files	11	3	8	0	0	1	8	Table 3:7
medium-cut files	4	3	1	0	0	4	0	Table 3:7
coarse-cut files	3	0	3	0	0	3	0	Table 3:7
shaft-hole axes	5	4	1	2	0	5	0	Table 2:1/6 (B5a), 2:1/18 (HNY33a); #; #; #
adzes	6	4	2	-	-	6?	0	Table 2:1/18 (HNY4b, HNY43b, HNY53b, HNY54a, HNY54b, HNY55a)
gouges/chisels	7	1	6	0	1?	6	2	Table 2:1/12 (D7b, D11a, D11b, D139, D158), 2:1/15 (HNY21b); #
saws	4	4	1?	0	0	4	0	Table 2:1/5 (BTC1a), 2:1/12 (D5a, D174), 2:1/18 (HNY64b); S69
pick/mattocks	2	2	0	0	0	2	0	Table 2:1/6 (B4), 2:1/18 (HNY27a)

α Incorporation of steel component at working edge
β Likely structure at manufacture (i.e. excluding spheroidized structures)
* Sample not from working edge
# Fiskerton (Fell forthcoming)

made. Data for the metalworking tools (first 7 entries) are derived primarily from Appendix B, but also include seven analyses from other studies (Table 2:1). The principal findings are:

(1) In woodworking chisels, the use of steel seems to have been common, and although only two had been quenched (Salter 1984, 435, nos 2.46 and 2.48), the hardness in other chisels was possibly adequate for cutting wood (cf. Tylecote and Gilmour 1984, 104). One of the quenched chisels from Danebury (2.46) may have had a high-carbon component welded into the centre of the blade (Salter 1984, 435).

(2) Axeheads are variable in carbon composition, and none is quenched. Two socketed axes, from outside the immediate area of this study and therefore not shown in Table 4:6, have been found to be metallurgically similar to the shaft-hole examples: one from Rahoy, Argyll (Desch 1938, 41-3), and one from Lough Mourne, Co. Antrim (Scott 1974a, 16), the latter possibly with a high-carbon area at the cutting edge.

(3) Saws, possibly for working materials such as wood or bone, or having an agricultural purpose, seem generally to be carbon-free or very low in carbon. Saws may have been surface-carburized, but no evidence for this has been reported, and none is quenched. Sample S69 in the present study, from a 'saw' from Fiskerton (Plate Ia), has a moderate level of carburization (p. 169). This sample comprises only surface corrosion products; it is not possible to determine if the carbon level is typical, nor if it derives from surface carburization.

(4) The other categories of edge implements which have been studied for metal structure in any number are swords and knives. The evidence from swords (McGrath 1968; Lang 1987) suggests that a different and possibly more advanced technology was sometimes employed. A number of the swords were forged from carburized components; layered constructions seem to be common, possibly to strengthen the blades. Surface carburization, cold-work, and quenching in weapons and knives is discussed above (Section 4.6.1).

(5) In currency bars, the generally low quality of metal in terms if abundant slag inclusions and lack of carburization which has been reported (e.g. Hedges and Salter 1979, 164-5; Ehrenreich 1985, 60, 73-4), suggests that these may have been metal stock, and possibly for non-specialised products. The higher carbon content of currency bars

from Beckford (Section 4.6.1.d) has been interpreted as deliberate enhancement of properties, and the low phosphorus in the same bars was attributed possibly to ore source (Hedges and Salter 1970, 165).

DISCUSSION

Despite the low sample size in any one category of artifact, the indications are that certain types of tools and blades were sometimes manufactured from higher quality iron, and involved more complex techniques. These include at least metalworking tools, woodworking chisels, and swords; it is possible that some ironworkers may have specialised in the manufacture of these products. Cold-work, and the piling of surface carburized strips, seem to have been employed occasionally for blades. The welding-in of steel components seems to have been very rarely practised; possibly this was related to the difficulty of welding iron and steel owing to their different hot-working temperatures (Chapter 1.3.3).

It may be relevant that edge tools and implements from the Roman period from Britain are generally reported to be of low technological level, though occasionally artifacts of high-quality occur (cf. Coghlan 1977, 122-3, nos 12 and 13; Tylecote and Gilmour 1986, 22-36, 59-106, tables A-K, 6 and 8). A decline in quality has been noted in some first century Roman swords when compared with swords of the later Iron Age, which has been suggested to be due to changes in organisation within the Roman army (Lang 1987; 1988, 209-10). Few Roman metalworking tools have been sampled (but see Tylecote and Gilmour 1986, table G on p.75, table G, p.79; Manning with Tylecote in Draper 1985, 46-8, table 7).

4.7. <u>Comparison of the edge metalworking tools from England with edge tools from the Continent</u>

I. <u>Metalworking tools</u>

A number of metalworking tools of Iron Age (or possibly early Roman) date have been examined from central and eastern Europe. Those for which metallographic data is most readily available (six hammers and six or more files) are listed below.

(1) Widderstatt, Germany: tools of late Hallstatt to late La Tène date. A socketed hammer comprises very low carbon and is not heat-treated (Hennig 1986, 181, no. 127/70). Four eyed hammers are piled

and unevenly carburized, varying from very low-carbon in two hammers which had not been quenched to medium-carbon in two quenched hammers (Hennig 1986, 182-7, nos 502/79, 275/71, 2455/69, 211/71, Abb. 12-14).

(2) Stradonice, Bohemia: a La Tène hammer is uniformly and well carburized, and quenched (Pleiner 1962, 264, no. 38, pl. XIX).

(3) Staré Hradisko, Moravia: a hammer is uniformly and well carburized, and quenched (Pleiner 1982, 92-3, no. 463, Abb.3, pl. 9, 7-9). A fine-cut file is also well-carburized and quenched, and shows enhanced carburization at the edges (Pleiner 1982, 92, no. 462, Abb. 3, Abb.7, 8, pl. 9, 1-6).

(4) Liptovská Mara, Hungary: a fine-cut file (unstratified) is well-carburized and quenched (Pleiner 1982, 95, no. 494, Abb. 7,7, pl. 22).

(5) Steinsburg, Germany: a fine-cut file is made of 'good-quality' steel (Spehr 1971, 500; 1975, 170). In addition, two other files were examined by Hanemann (1921-2) which are 'not later in date than Roman' (Coghlan, 1977, 79); both are well-carburized and quenched.

(6) The Magdalensberg, Noricum: three first century BC fine-cut files are well-carburized and quenched (Schaaber 1963, 183-9, V32.26-28, Taf. XXIV-XXVIII; also 1972). The overall level of technology applied to other tools and implements from Noricum is also high; the quality of ores was noted by Pliny (*Natural History* IX. 34,145).

II. <u>All edge tools</u>

Pleiner has studied edge tools and implements from sites in Czechoslovakia, ranging from Hallstatt to late La Tène date (Pleiner 1962; 1980; 1982; 1985). By comparing artifacts of late La Tène date from eight sites he observes certain trends. In 65 tools and implements, including four metalworking tools (nos 2-4 above), woodworking tools, agricultural blades, and knives, were determined as follows: carburization above *c.* 0.3% occurs in 75%, surface-carburization in 22%, piling of surface-carburized iron in 15%, welding-in of steel components in 10% (Pleiner 1985). Of the artifacts made of hardenable steel (above 0.3% C), 68% had been quenched (Pleiner 1982, Abb. 8).

Pleiner suggests that different technologies were employed for various types of tools and implements. Surface carburization (with or without piling) and welding-in of steel was used commonly for woodworking chisels, and blades for agricultural, weaponry, and domestic purposes (Pleiner 1980, 404-5, fig. 11.12, table 11.4; 1982, Abb. 4-7). In these artifacts, the technology is suggested to have been of advanced level, and occurring in a greater proportion than in similar types of tools and implements from late Hallstatt and early La Tène sites (Pleiner 1980, 388-9, table 11.1). A different technology appears to have been applied to hammers and files. In the four examined, well-carburized steels of more uniform composition were employed, and all were quenched.

In Figure 4:5, the 41 edge metalworking tools from England examined in the present study are compared with assemblages of edge tools and implements from the Continent. Figure 4:5 is expressed in terms of technological groups according to the system devised by Pleiner (1982), discussed earlier (p. 199). The assemblages are not comparable in content; those from the Continent comprise largely agricultural blades, plus a few edge metalworking tools (listed above), and other edge tools. Functional differences of artifacts in the groups, ore source, and smelting techniques, may account for the main variations between the assemblages.

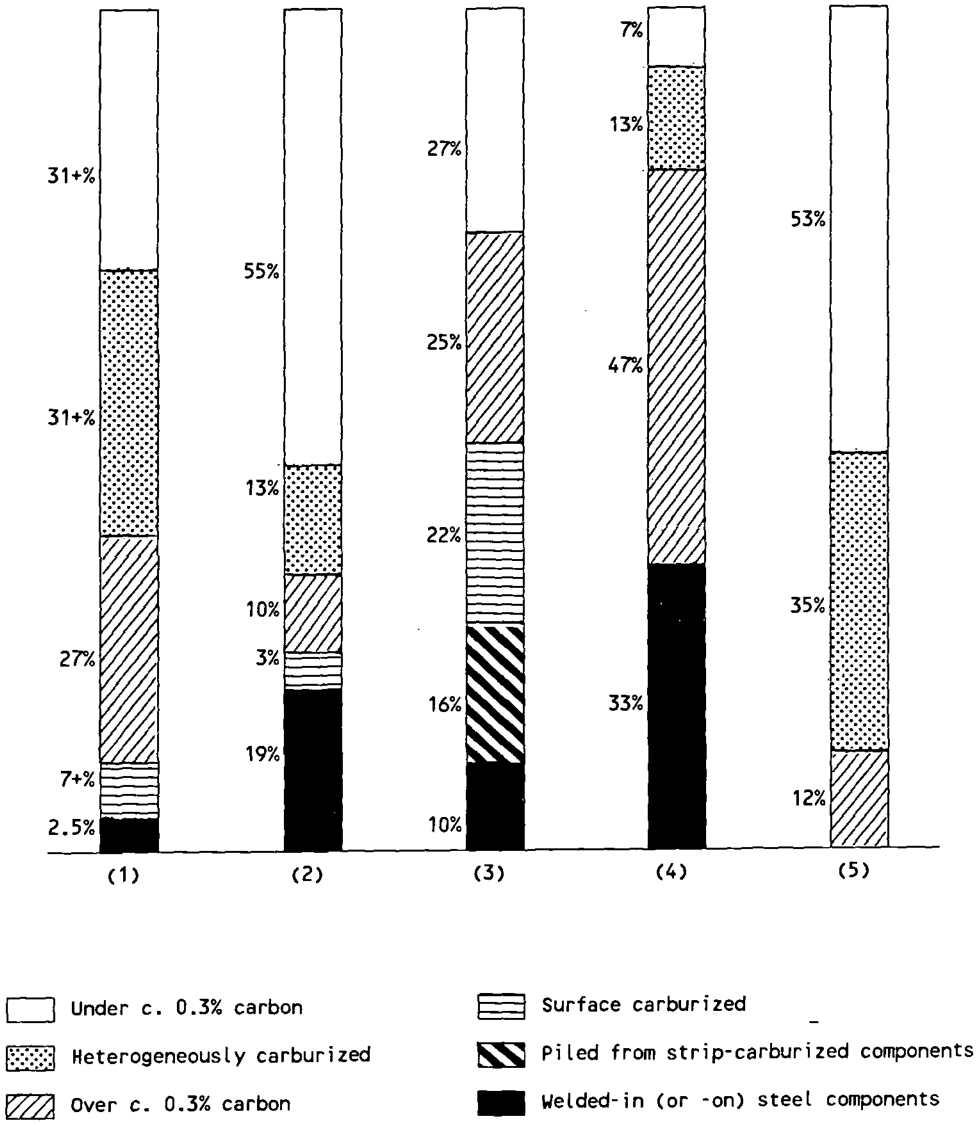
III. <u>Discussion</u>

From the data discussed above (Sections 4.6.*I-II*, and 4.7.*I-II*), the principal conclusions are:

(a) The technology applied to hammers and files may be similar in those from England the Continent regarding the use of relatively evenly carburized irons and quenching, though a greater proportion of those from the Continent were made of high-carbon steels.

(b) The welding-in of steel components and of surface-carburization (whether restricted to the surface or piled into the metal structure) seems to have been more frequently practised on the Continent, and employed principally for weapons, knives, axes and woodworking chisels (see also Pleiner 1980, tables 11.3 and 11.4; Hennig 1986, Abb. 21). However, more thorough analysis of chisels and edge implements from Britain, for carbon distribution in particular, is required before realistic comparisons may be made.

(c) The different technologies between *(a)* and *(b)* above may reflect functional requirements, selection of steels for hammers and files, specialisation of the metalworkers and thus possible different technologies, or a combination of these (or other) factors.



(1) England: 41 Iron Age edge metalworking tools

(2) Widderstatt, Germany: 31 late Hallstatt to late La Tène edge tools and implements (5 hammers, 5 woodworking tools, 6 agicultural implements, and 15 knives). Source: Hennig 1986, Abb. 21

(3) Czechoslovakia, 8 sites: 59 La Tène edge tools and implements (2 hammers, 2 files, 14 woodworking tools, 2 saws, 6 agicultural implements, and 33 blades [24 knives, 3 razor, 4 shears, 2 weapon]). Source: Pleiner 1982, Abb. 8, Tab. 3

(4) The Magdalensberg, Noricum, Austria: 15 late La Tène edge tools and implements (4 files, 3 knives, and 8 others, mostly agicultural implements). Source: Hennig 1986, Abb. 21 (after Schaaber 1977)

(5) Steinsberg, Germany: 66 La Tène tools and implements. Source: Hennig 1986, Abb. 21 (after Spehr 1975)

Figure 4:5 Technological groupings of edge tools from England and the Continent

4.8. Summary

The Iron Age metalworking tools sampled are 41 edge tools and 6 hearth implements from England. Of the samples, 66% were relatively well-carburized comprising at least 0.3% carbon (Table 4:1), though the distribution was frequently non-uniform. Analysis suggests that carburization was derived principally from the bloom, and that carburized blooms were very probably selected for the tools. Possible surface carburization is indicated in three chisels. It seems unlikely that phosphoric irons were employed deliberately; where phosphorus and other impurities were present, this was probably due to segregation effects during smelting and subsequent forging.

In the 41 edge tools sampled, 68% comprised at least *c.* 0.3% carbon in the area examined (Table 4:1), and 18 had been quenched: 10 hammers, 7 files, and a possible cold set (Table 4:2b). Of the edge tools which comprised hardenable steel (above *c.* 0.3% carbon), 13 (46%) had been quenched (Fig. 4:2). However, many of the tools were non-uniformly hardened, principally due to heterogeneity in carbon composition. The earliest incidence of quenching occurred in tools potentially dating to the fourth century BC. Functional differences between individual types of tools probably accounts for selection for quenching (e.g. specialised hammers and fine-cut files). Technological trends could not be established either geographically or chronologically, mainly because of the small sample size in any one category of tool (Table 4:5).

Comparison of the metalworking tools with other categories of Iron Age artifacts from Britain (from published sources, Table 2:1), suggests that carburization was much more common in the former, and a far greater proportion had been quench-hardened. The variation in technology between different categories of artifacts (Table 4:6) is again likely to be related to function, but may also reflect specialisation of the ironworkers, or that certain techniques were not commonly known.

Comparison of hammers and files from Britain with hammers (6) and files (6) from six sites in central and eastern Europe (Section 4.7) suggests similar technology, whereas other edge tools and implements from Britain (e.g. blades) appear to have been less advanced than the continental examples.

CHAPTER 5

THE TOOLS IN THEIR ARCHAEOLOGICAL CONTEXT

5.1. Introduction

This chapter examines the archaeological contexts of the ferrous metalworking tools, and the evidence for functional and social use.

Sections 5.2.1 - 5.2.5 analyse the material evidence for metalworking activity at five settlements from which a number of ferrous metalworking tools were recovered in association with metalworking debris or possible metalworking areas (Gussage All Saints, Weelsby Avenue, Glastonbury, Meare Village West, Meare Village East). Section 5.2.6 examines six other occupation sites from which there is evidence for metalworking, but from which few tools were recovered (Beckford, South Cadbury, Fison way, Wetwang Slack), or from which the tools were from deposits unrelated to the metalworking activity (Danebury), or were discovered during quarrying (Hunsbury). These are other key sites with metalworking activity, but where full information is not yet available or where metalworking associations cannot be determined. The occurrence of tools with metalworking residues is discussed in Section 5.3.

Metalworking tools from groups of metalwork ('hoards') from six occupation sites (Garton Slack, Madmarston, Bulbury, Hod Hill, Barbury Castle, Bigbury) are analysed in Section 5.4 in terms of attribution of the groups and likely dating.

Tools from four groups recovered from away from occupation sites (Waltham Abbey, Fiskerton, Llyn Cerrig Bach, Santon) are analysed in Section 5.5.

Tools from five or more burials are discussed in Section 5.6 (Rudston, King Harry Lane, Whitcombe, Witham Bury).

The evidence for metalworking activity, functional and social use of the tools, and the geographic and chronological distribution of the tools are discussed in Section 5.7.

5.2. <u>Key occupation sites</u>

5.2.1. Gussage All Saints, Dorset

The enclosed rural settlement site at Gussage All Saints (Wainwright 1979), examined in its entirety, yielded debris from bronze casting and wrought working, and iron smelting and smithing. The occurrence and distribution of the metalworking debris, in particular the evidence for non-ferrous metalworking, is discussed by Spratling (1979), who suggests that there is some evidence for both bronzeworking and ironworking during all three phases of settlement (Spratling 1979, 125, tables XIV and XV).

The chronology of the site, based on radiocarbon, ceramic, and stratigraphic evidence, is discussed by Wainwright and Switsur (1976). They suggest that the Phase 1 settlement dates from around the middle of the first millennium BC or a little earlier, up to the beginning of the third century BC, Phase 2 to the first three centuries BC, and Phase 3, the final period of settlement, up to the third quarter of the first century AD.

Based on stylistic evidence from the mould fragments, pit 209 (Phase 2), which contained the largest accumulation of metalworking debris, is assigned to the first century BC (Spratling 1979, 125; but cf. Collis 1982). Two radiocarbon determinations on charcoal from the lower layers of pit 209, layer 10B and layer Y (corresponding to layer 12), gave ages of 150±65 bc (Q1207) and 70±70 bc (Q1206), or in calibrated Calendar years 355 - 20 BC and 165 BC - AD 80 respectively (Wainwright and Switsur 1976). The sampled charcoal was from large timbers, which together with the limitations of the technique, does not enable a relationship between the dates for the two layers to be sought, though does agree with the artifactual evidence.

Another two samples from Phase 2 features with metalworking debris, from pit 437 layer 5 (Q1205), and from ditch 1M layer 4 (Q1201), gave ages of 210±75 bc and 230±75 bc respectively, calibrated to Calendar years 400 - 120 BC and 415 - 150 BC. Thus, there is a possibility that the debris from these features predates that from pit 209 (Spratling 1979, 125; Foster 1980, 37).

The evidence for metalworking is examined below in the following sequence: I, the nature of the metalworking debris; II, the ferrous tools; III, other ironwork from pit 209; IV, the evidence according to phase of settlement; V, synthesis.

I. The nature of the metalworking debris

I.a. Foundry debris

The foundry debris was concentrated in features close to the entrance of the settlement, occurring in: pit 209, pit 437, pit 438, segment 1M of the enclosure ditch (all Phase 2); hollow F2, segment 1K of the enclosure ditch (Phase 3); and in pit 857, an undated pit in hollow F2, which may belong to Phase 2 or Phase 3 (Wainwright 1979, 32). A few isolated finds of debris from all three phases were found in other features, including contexts up to 100m away from the entrance.

The greatest concentrations were from Phase 2 features, and in particular, the lowest layers (layers 10-12) of pit 209. The mould fragments are all investment moulds from *cire perdue* casting, and were solely from the production of harness and chariot fittings (Foster 1980). These include strap-unions, three-link 'Arras' type bridle-bits, stop knobs for bridle-bit rein-rings, four types of terrets with numerous variants, vase-headed linch-pin terminals, and button-and-loop fasteners (Spratling 1979; Foster 1980). It has been estimated that the foundry debris represents the manufacture of approximately fifty sets of harness and chariot fittings (Spratling 1979, 140). The finds from pit 209 which may have been connected with founding are:

(1) 7318 fragments of moulds (Foster 1980, 7)
(2) Four bone spatulae considered to have been for the forming of wax models for *cire perdue* (Spratling 1979, 141, fig. 98, 2-5)
(3) Nearly 600 fragments of crucibles, from which at least thirty crucibles have been reconstructed (Spratling 1979, 130)
(4) Copper alloy slag, droplets, and cast lumps (at least 300 pieces)
(5) Tuyères and hearth lining, much of which has been attributed to non-ferrous metalworking (Spratling 1979, 129)
(6) Unfired clay (Spratling *et al.* 1980, 280), fuel ash slag, and charcoal fragments (Spratling 1979, 127-9).

Not all the residues in (3) to (6) above need have derived from founding, but could include debris from other non-ferrous processes such as metal refining and preparation, or from plating metalwork, whereas the waste material in (6) above could have derived from bronze working or ironworking.

From features 2, 437, 438, and 857, another *c.* seventy-eight fragments of moulds were recovered, though these are more weathered than those from pit 209 (Foster 1980, 44-5). Other debris from these features includes crucible sherds, copper alloy metallic waste, and hearth matrix (Spratling 1979, table XIV).

Spectrographic analysis of five samples of metal adhering to crucibles, metal within a sprue-cup, and two droplets of metal, have shown tin bronzes with six of the eight specimens containing appreciable lead (Spratling *et al.* 1980, 280). Metallographic analysis of another nine fragments of cast metal and droplets indicated 10-16% tin contents (Tylecote 1975, 1-4). From these analyses, it seems that the alloys in use during Phase 2 were tin bronzes (± lead), of typical Iron Age composition (cf. p. 30).

I.b. Non-ferrous wrought metalworking debris

Evidence for non-ferrous wrought metalworking comes principally from three partially formed copper alloy objects, each bearing tool marks presumably from hammering:

(1) A bronze billet from pit 209 comprising *c.* 11% tin (Spratling 1979, 130, fig. 98, 1; Spratling *et al.* 1980, 282, no. 85)

(2) A small bar or billet from pit 65 (Wainwright 1979, 109, no. 3074), listed in the metalwork catalogue as Phase 1, but the feature is Phase 3 (Spratling 1979, table XV)

(3) A fragment of unfinished sheet from pit 711, a Phase 3 feature (Spratling 1979, 125; Wainwright 1979, 113, no. 3064, fig. 87).

In addition, pit 209 yielded many small fragments of sheet metal, some of which are certainly scrap, as well as many tiny pieces which may have been scrapings from the finishing of objects.

I.c. Ironworking debris

Unfortunately there has been no evaluation of the ironworking slag in terms of phasing, distribution, or process. Some apparently was from 'the earliest levels' (Clough 1986, 183-4). According to Spratling (1979, 125), iron was forged during the earliest phase though it is unclear whether the evidence was deduced from debris or from finished products (which could have been imported). From the whole of the site, some 700kg of ironworking slag was recovered. This includes smelting slag, some which had been tapped or raked, smithing slag and hammerscale, and at least one plano-convex smithing hearth bottom (Clough 1985, 184; 1986, 182-4). However, the only metalworking feature which survived was the base of an iron-smelting furnace attributed to Phase 3 (Wainwright 1979, 32, fig. 24, pl. XXXIII), below which was sealed a sherd of Samian probably of Claudian date (Spratling 1979, 125; Wainwright 1979, 88, no. 6021).

Amongst the debris in pit 209 was abundant flake hammerscale and many pieces of iron slag (Wainwright and Spratling 1973, 119; Spratling 1979, 127; Spratling *et al.* 1980, 269). Also from pit 209 is a large quantity of unpublished iron finds which includes tools and iron smithing debris, discussed in **(III)** below.

I.d. Composite technology

There is evidence to suggest that the manufacture of harness and chariot fittings involved composite cast bronze with iron, and bronze coatings or claddings over iron. Some of the mould fragments from pit 209 were possibly for casting-on copper alloy feet to the iron shanks of linch-pins (Foster 1980, 19).

From pit 209 is a discarded steel link from the mouth-piece of a 'Llyn Cerrig Bach' type bridle-bit which is coated with bronze (Spratling 1979, 129, fig. 97). The link, examined metallographically by Tylecote, is coated with bronze over a layer of tin, probably to facilitate easier coating at the high temperature required (Spratling *et al.* 1980, 286-291, no. 3). Another artifact, an iron pin from pit 209, is clad with bronze sheeting, which was cast as sheet and then hammered onto the iron pin (Spratling *et al.* 1980, 284-6, no. 24).

II. The ferrous metalworking tools

The distribution of the ferrous tools is shown by phase of settlement in Table 5:1.

Probable iron-smithing tools comprise a hot-chisel (No. 102), two possible cold sets (Nos 114 and 116), and three hot punches (Nos 164, 166, 167).

The other tools are likely to have been used for cold-working techniques - for finishing and decorating metal. These are at least six, but possibly eight, fine-cut files (Nos 126, 137, 143, 152-156), sixteen cold punches (Nos 169, 174, 175, 182, 186, 188, 191-198, 190, 202), five ?gravers (Nos 207, 215-218), three ?scorers or scribers (Nos 221, 228, 229), and a ?scraper/burnisher (No. 230). Foster (1980, 22) has commented on the roughness of internal surfaces on some of the mould fragments from pit 209, and it seems possible that the

Table 5:1. Distribution of metalworking tools at Gussage All Saints

Tools	Phase 1 contexts	Phase 2 contexts			Phase 3 contexts	Total
		pit 209	pit 437	other		
Hot chisel	-	-	-	-	1	1
?Cold sets	-	1	1	-	-	2
Hot punches	-	1	2	-	-	3
Files	-	5	1	-	2	8
Cold punches	2	6	2	2	4	16
?Gravers	-	5	-	-	-	5
Other	-	3	1	-	-	4
Total	2	21	7	2	7	39

files and the ?scraper/burnisher may have been used to finish castings. Three of the files (Nos 126, 152, 156) have copper alloy inclusions in their cuts (p. 140-2). The cold punches, some of which were possibly chasing tools, and the ?gravers, may have been used for decorating sheet metal or to add or refine detail on castings. These finishing and decorating tools were concentrated in pits 209 and 437; nineteen of the thirty-three are from layers 10-12 of pit 209, and four are from pit 437. The other ten tools were recovered as single finds, of which only a punch (No. 194) was in a feature (Phase 1) which contained any metalworking debris.

The spatial distribution of the tools and metalworking debris from each of the three phases is discussed in **IV** below, together with the possibility of residuality of finds.

Another iron artifact which may conceivably have had a metal working purpose is a hooked block from a Phase 1 context (Wainwright 1979, 104, no. 1019, fig. 80) similar to one discovered at Barbury Castle (Macgregor and Simpson 1963, 396, no. 26) which had there been used as an anvil. The block from Gussage All Saints seems unlikely to have been used as an anvil, but the type is discussed in Chapter 3.4.

Seven of the tools from Gussage All Saints have been examined by metallography, one in the present study, and six by Tylecote (Tylecote 1975, 5-7, 11-13; Spratling *et al*. 1980, 284-5). The results are summarised in Table 5:2.

Table 5:2. Summary of metallography of tools from Gussage All Saints

Tool	Phase 2 pit 209	Phase 2 pit 437	Phase 3	Source
?Cold set No. 116:				Tylecote 1975, 5-6, no. 283;
edge	C Q (473-532)			Tylecote and Gilmour 1986,
stem	Q (208-401)			86-8, fig. 36
File No. 126: blade			B Q (613)	Appendix B, S51
File No. 143: blade		B Q (313-358)		Tylecote 1975, 6-7, no. 822
Punch No. 164: stem	B (214-252)			Tylecote 1975, 6, no. 510
Punch No. 167: stem		A (166-227)		Tylecote 1975, 7, no. 834
Punch No. 169: stem	C (274-296)			Tylecote 1975, 6, no. 575
Punch No. 199: stem		A (202)		Tylecote 1975, 7, no. 824

A - below c. 0.3%C, B - unevenly carburized, C - above c. 0.3%C, Q - quench-hardened
Bracketed figures are hardness values HV5

III. Iron finds from pit 209

It is relevant to examine the content of the ironwork assemblage from pit 209 since attribution of many of the small tools (Chapter 3.10) is based on their presumed association with the metalworking debris, and the nature of the iron-smithing waste which is present.

The assemblage of iron finds from layers 10-12 of pit 209 comprises 735 accessioned groups (made up of *c*. 1638 individual artifacts and fragments). These were listed by Dr. Mansel Spratling, but they have never been thoroughly analysed, nor published. The original conservation was restricted to X-radiography, desalination, and consolidation (Ridgway 1974). The artifacts are severely corroded, distorted, and unstable, which makes recognition of individual artifacts difficult; they have been described as 'unrecognisable lengths of corrosion products' (Stead 1985b, 10).

The identity numbers given below for items not catalogued in this study are the temporary accession numbers accorded in the British Museum Department of Prehistoric and Romano-British Antiquities (BMP) by Dr. Spratling, and/or Ancient Monuments Laboratory (AML) accession numbers. Evidence based mainly on X-radiography, but also from selective removal of accretions (where asterisked) suggests that the assemblage comprises tools, a few domestic items, and a considerable amount of iron-smithing waste. The assemblage includes the following:

(1) A few complete artifacts including a knife (BMP131/AML726515), 2 small bladed implements (AML726216 and AML726218), a hooked blade (AML728607), a needle (BMP740/AML728550), a pointed implement with copper alloy ferrule (AML726552), 15 rivets and nails

(2) Fragments of objects, probably discarded broken items, e.g. a socket fragment of a large ?agricultural blade (AML728598), a knife-blade (AML726892), and a saw-blade (AML726227)

(3) Twelve complete metalworking tools* (discussed in **II** above)

(4) Nine broken metalworking tools* (discussed in **II** above)

(5) Numerous incomplete rods which may very well have been fragments of metalworking tools, including rods of tapering square-section (e.g. BMP305/AML726225*), trapezoidal-section (e.g. BMP671/AML728428*), and round-, oval-, and rectangular-section

(6) Complete tanged tools or implements of lengths less than 50mm, possibly metalworking tools, awls, and other implements (e.g. BMP370/AML726894 and BMP636/AML728437)

(7) Two tangs, both with traces of round-sectioned stems (BMP286/AML726207* and BMP382/726680*)

(8) Several tips of fine rods (e.g. BMP322/AML726880, BMP795/AML728615, AML728546, and AML726731)

(9) Fragments of rod and bar which were possibly part-formed items (e.g. BMP483/AML726828* and BMP737/AML728547*), and shaped tips of bar which may have been off-cuts (e.g. BMP302/AML726223*, AML726564, AML726596, AML726671, AML726741, and AML728533)

(10) Numerous fragments of sheet, strip, rod and bar, some bent or folded, possibly discarded items or off-cuts from smithing (e.g. AML728385, AML728399, AML728508, AML728511, AML728527, AML728532)

(11) Abundant hammerscale and other smithing slag.

The layer immediately above the concentration of metalworking debris in pit 209, layer 9, contained some foundry debris and a small quantity of domestic refuse including animal bones and potsherds (Spratling 1979, 126). Although some of the items listed in *(1) and (2) above* may have derived from layer 9 and thus from domestic use, the majority are from the two lowest layers (layers 11 and 12).

Some of the bars and rods in the assemblage, *(9) and (10) above*, may have been debris from the production of iron bridle-bit links or shanks for linch-pins. It is very probable that many of the fragments of rods, *(5), (6), (7), and (8) above*, are from tools, particularly those of square, rectangular, or trapezoidal cross-section, although none retain sufficient attributes which allows them to be identified with certainty. There are a few nails in the assemblage, but because of their small size, incomplete nails are unlikely to be confused with fragments of possible tools. Fragments of tapering rod of narrow round cross-section may be broken wax-modelling implements, scribers or other tools - or pins, awls, needles, or other artifacts.

It seems very likely that many additional but fragmentary metal-working tools may have been deposited in pit 209. It is relevant to add that the five files identified from this assemblage are merely short fragments, whereas the other tools identified are complete or nearly complete (and thus recognisable), but presumably many other broken tools may be expected in this assemblage.

IV. The evidence according to phase of settlement

Phase 1 (Figure 5:1)

Evidence for metalworking during Phase 1 of the settlement is comparatively slight (Table 5:3). There are five lumps of cast bronze, one of which came from a feature (pit 292) which also yielded a punch (No. 194). Three other lumps of bronze were found in pits adjacent to those which yielded the two metalworking tools from Phase 1, suggesting that metalworking during Phase 1 may have occurred to the east side and to the west side of the settlement. The evidence for iron working is unclear; Spratling suggests that iron was forged during

Table 5:3. Summary of metalworking evidence from Gussage All Saints

	Phase 1	Phase 2	Phase 3
Bronze-founding	5 cast lumps	much debris	some debris
Bronze-smithing	-	billet	1 bar, 1 sheet
Iron-smelting	?	?	furnace, slag
Iron-smithing	?	slag	?
Fe/Cu composite	-	2	-
Ferrous tools	2	30	7
Bone implements	-	4	-

Sources: Wainwright 1979, 104-113; Spratling 1979, tables XIV and XV; Clough 1986, 182-4

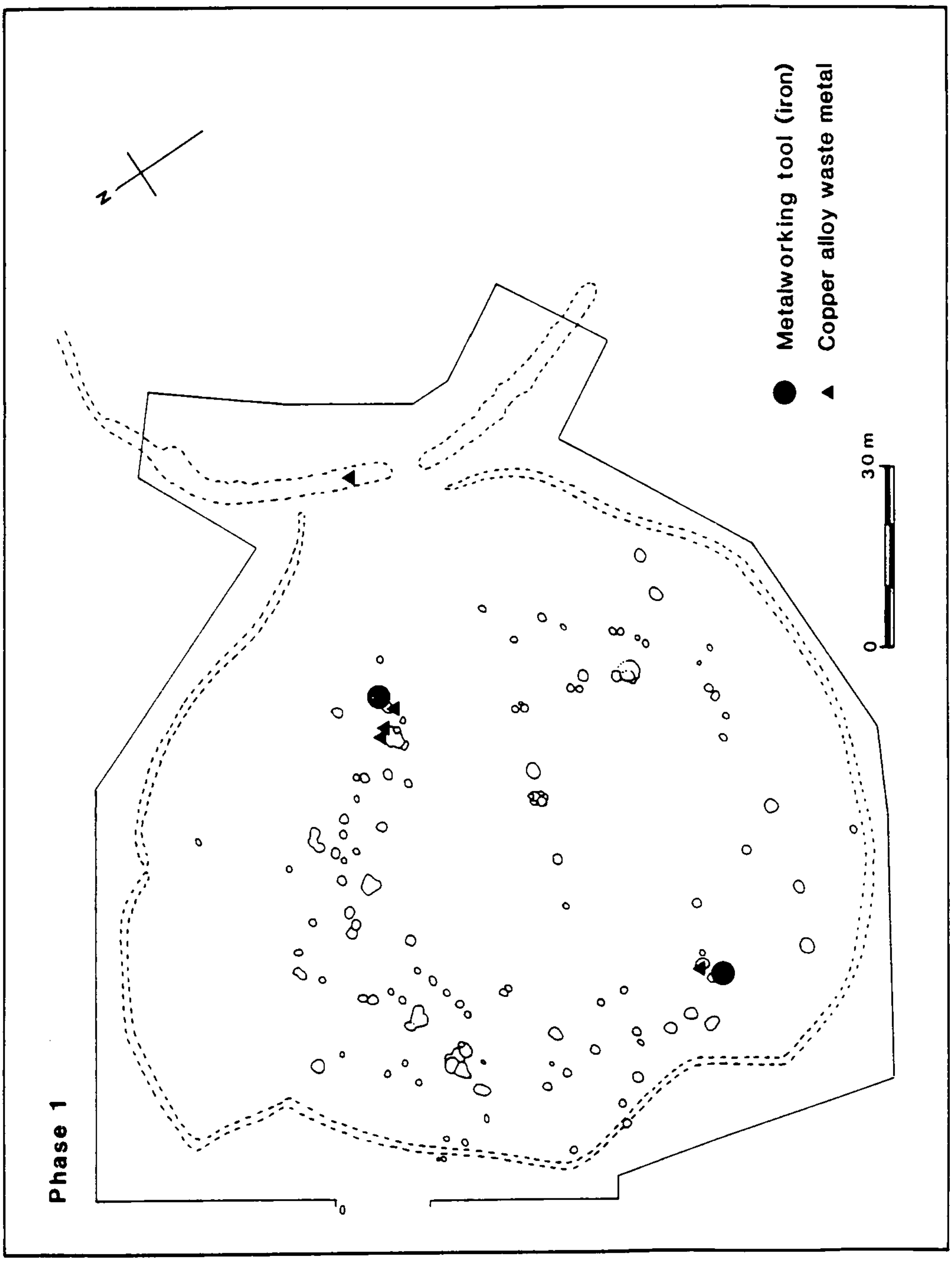


Figure 5:1 Gussage All Saints Phase 1: distribution of metalworking debris and tools

Plan after Wainwright 1979, fig. 16

this phase (Spratling 1979, 125), and ferrous slag has been reported (Clough 1986, 182-4), but there is no supporting information in the reports.

Phase 2 (Figure 5:2)

The Phase 2 features which yielded tools and bronzeworking debris were close to the entrance, except for three adjacent pits to the west side of the settlement which together yielded two tools and a lump of cast bronze.

The debris from pit 209 in particular suggests that there was considerable ironworking activity concurrent with the bronze-founding during the first century BC. Again the ferrous slag from this phase of settlement has not been assessed and thus the nature and extent of this activity cannot yet be determined.

From pit 209, the evidence from joining fragments of moulds and joining fragments of crucibles, together with the unweathered appearance of fractures on mould fragments, has led Foster to suggest that the foundry debris in layers 9-12 accumulated over a relatively short period (Foster 1980, 33, 37). She further suggests that the debris may have been the waste from a single event, possibly from itinerant metalworking activity (Foster 1980, 37). However, Spratling has carefully argued against itinerant activity, basing his reasoning on the quantification of materials required for the numerous and complex operations involved (Spratling 1979, 141-9).

The distribution of the ferrous tools in pit 209 (nine from layer 10, ten from layer 11, two from layer 12) is similar to the relative proportions of the mould fragments from each layer. A greater number of bridle-bit moulds are from layers 10 and 11, whereas terret moulds are concentrated in layer 12 (Foster 1980, table 4), but whether the distribution of the tools reflects use on any particular category of metalwork is speculative. (The two iron-smithing tools from this pit are from layers 10 and 11; none of the terret moulds suggest composite iron/bronze technology.)

Pit 437, which yielded seven ferrous metalworking tools, may possibly predate pit 209, though there is no certain association of the dated charcoal with metalworking activity (Spratling 1979, 125). Pit 437 comprised layers 3 - 6 (Wainwright 1979, fig. 15). Three of the tools came from the top layer including two of the three iron-

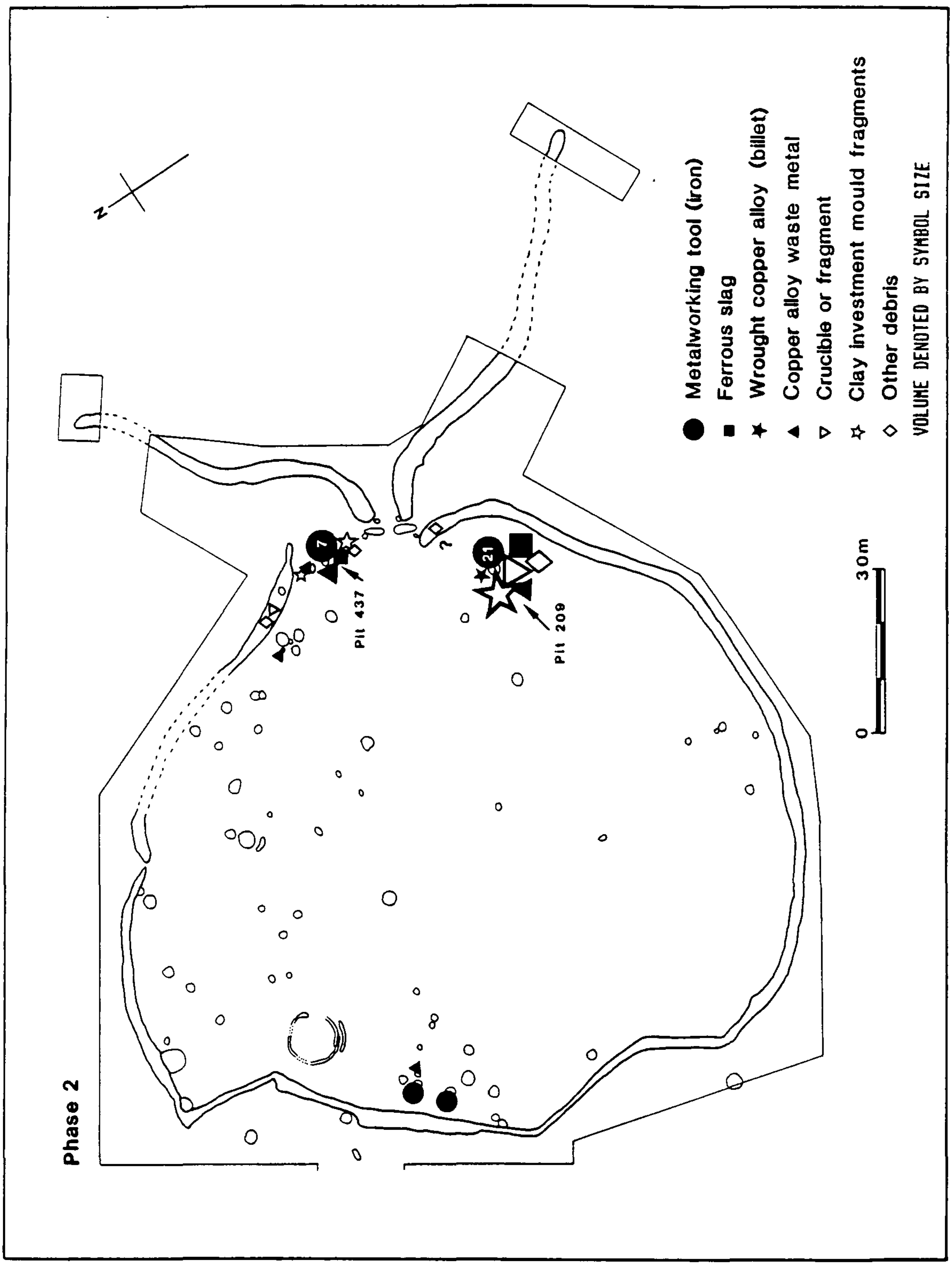


Figure 5:2 Gussage All Saints Phase 2: distribution of metalworking debris and tools

Plan after Wainwright 1979, fig. 17

smithing tools, and the rest from layer 5. Mould fragments and waste bronze metal were recovered from all four layers (Spratling 1979, table XIV; Foster 1980, 45), and in addition, there was ferrous slag from at least layers 3 and 5 (evidence from X-radiographs).

Pit 438 (adjacent to pit 437), pit 442, and segments 1M and 1Ka of the enclosure ditch, each contained a limited amount of metalworking debris (Spratling 1979, table XIV). Pit 857, which yielded evidence of bronze founding (Spratling 1979, table XIV) and ironworking (evidence from X-radiographs), cuts the Phase 2 enclosure ditch, and may belong to Phase 2 or to Phase 3 (Wainwright 1979, 32; Spratling 1979, table XV). For convenience, the debris from this pit is aggregated with that from hollow F2 (Phase 3) in Figure 5:3.

Phase 3 (Figure 5:3)
There are arguments that the Phase 3 bronzeworking debris from contexts near the entrance may be residual from the intensive earlier activity, though Spratling (1979, 125) suggests that bronzeworking (and specifically wrought working) probably continued into Phase 3. There is evidence for iron-smelting during the latter part of Phase 3, indicated by the base of a furnace in hollow F2. Only one-half of this hollow was excavated, but it cuts the Phase 2 enclosure ditch and incorporates the undated pit 857, as well as Phase 3 deposits which yielded bronzeworking debris (Wainwright 1979, 32; Spratling 1979, table XIV). The seven tools from Phase 3 contexts were distributed across the site, and it seems likely that some at least were connected with Phase 3 activity rather than having been residual.

V. <u>Synthesis</u>
(1) The distribution of the metalworking debris suggests that bronze and iron were worked during all three phases of settlement, though there is insufficient evidence to indicate that bronze founding, bronze-smithing, iron-smelting, and iron-smithing occurred during all phases. Thus, metalworking spanned four or more centuries, and may have been a regular though intermittent activity (Spratling 1979, 141;

(2) The only structure related to metalworking which survived was the base of the iron-smelting furnace 0.6m below present ground surface. Clough (1986, 183) suggests that this furnace alone could not have produced all of the smelting slag recovered from Gussage All Saints.

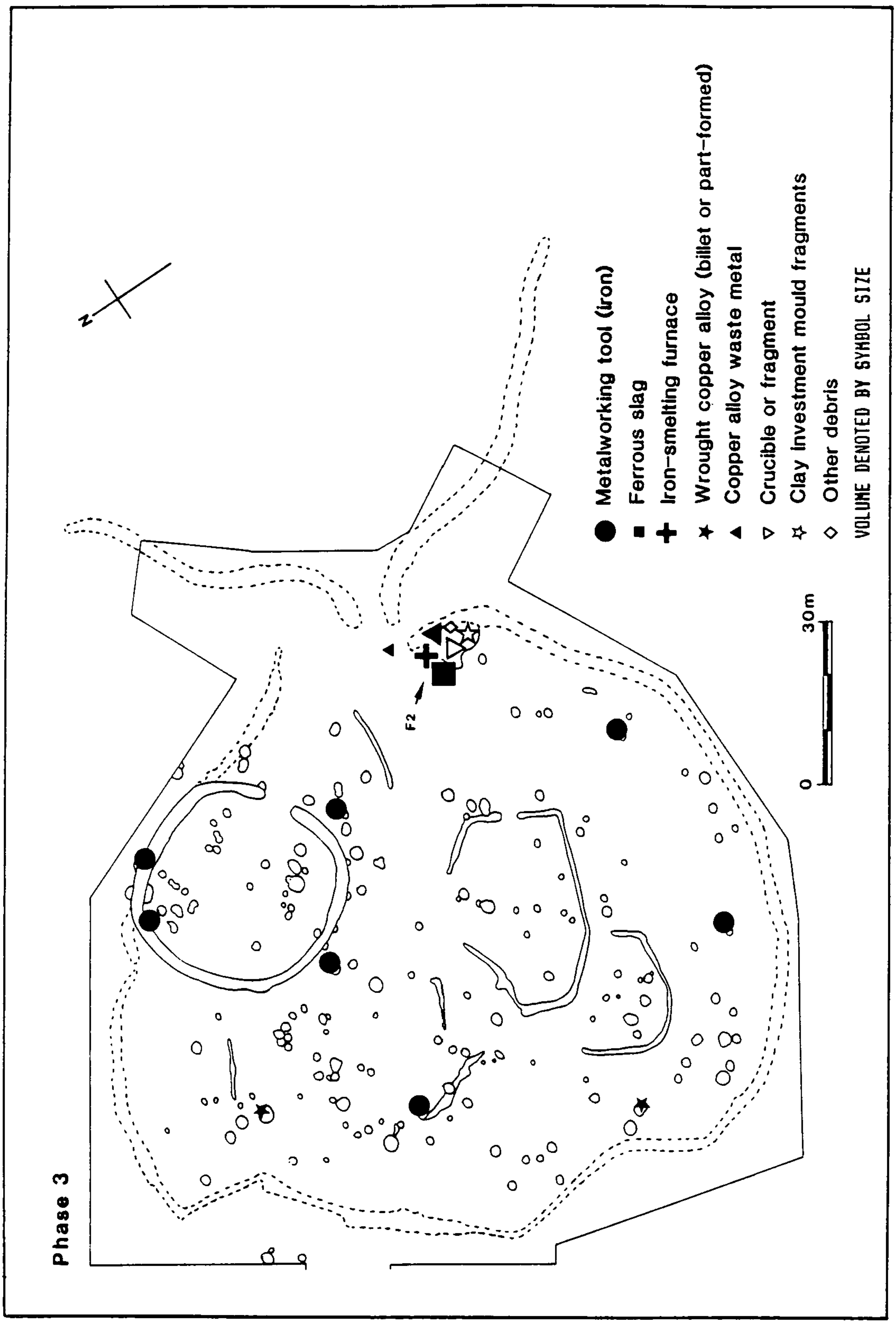


Figure 5:3 Gussage All Saints Phase 3: distribution of metalworking debris and tools

Plan after Wainwright 1979, fig. 19

Occupation levels were largely destroyed by later ploughing; a few gullies survived but only one roundhouse, assigned to Phase 2 (Wainwright 1979). It is possible, therefore, that other ironworking areas may have been lost, as well as the bronzeworking areas, and maybe other deposits of metalworking debris.

(3) The principal group of metalworking debris published, from pit 209, comes from the first century BC casting of chariot and harness fittings - prestige goods intended for distribution (Spratling 1979). The assemblage of Iron Age mould fragments is unmatched elsewhere in Britain (if not also in Europe). This assemblage, excavated in 1972, demonstrated conclusively that *cire perdue* casting was practised during the Iron Age and on a large-scale - a metalworking technique which was previously assumed from structural forms of artifacts and the occasional clay core (e.g. Spratling 1972, 255-7).

(4) The concurrent iron-smithing, attested by the ironwork assemblage from pit 209, may have been primarily for the production of tools, implements, domestic items for local use, probably iron components for the chariot fittings, and there must surely be a strong possibility that some of the metalworking tools were made at Gussage All Saints.

5.2.2. Weelsby Avenue, Grimsby, South Humberside

The rural settlement at Weelsby Avenue (Fig. 5:4) excavated 1977-1990 by J. Sills, has been examined almost in its entirety apart from one short stretch of the outer ditch. The description of the site and of the finds given below is based on information provided by J. Sills in advance of full analysis of the material and interpretation of the site. The foundry debris is currently being analysed by Jennifer Foster.

Based on the pottery evidence, Phase 1 of the settlement is tentatively assigned to the beginning of the first century BC, Phase 2 to the first half of the first century BC, and Phase 3 from around the middle of the first century BC until *c.* AD 25, but with the main occupation during this phase dating to the first century BC. A ditch (Phase 4) dated to the Roman period cuts the north side of the enclosure ditch, but no Romanised pottery has been found within the area of Iron Age occupation.

The site was discovered in 1970 after council workmen had re

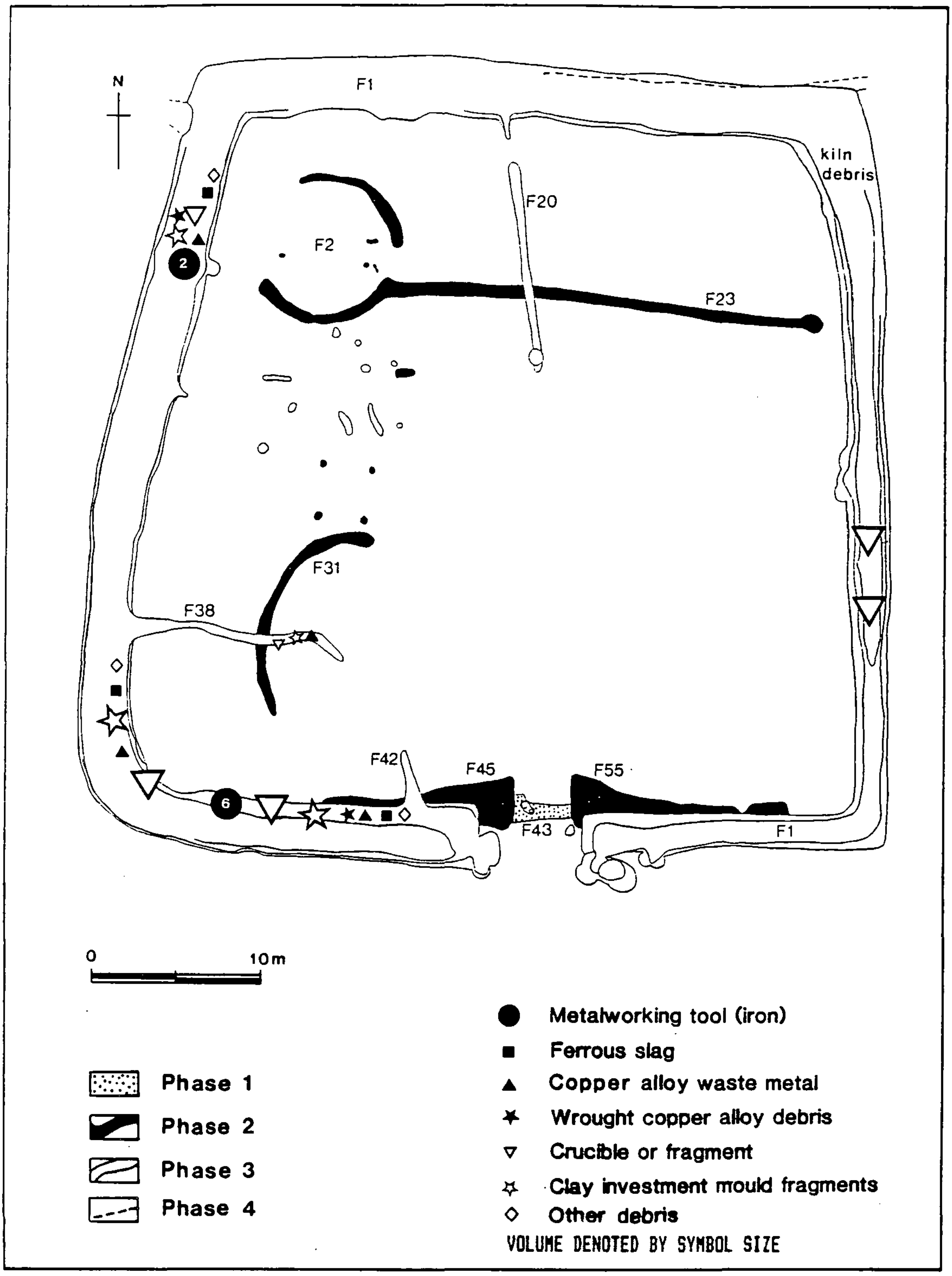


Figure 5:4 Weelsby Avenue: distribution of metalworking debris and tools

Plan supplied by J. Sills

moved topsoil by bulldozing. As a result of this, part of the interior of the enclosure had been stripped of archaeological features. The features which survived included the enclosure ditch assigned to Phase 3, the gullies of two Phase 2 roundhouses (F2 and F31) and the gully (F20) of a possible Phase 3 roundhouse. In the south-west corner of the settlement, close to the entrance, was a sub-enclosure defined by features F38 and F42. The quantity and distribution of metalworking debris found in the enclosure ditch and feature F38 suggests that the sub-enclosure may have been a metalworking area during Phase 3. No traces of hearths have been found.

The evidence for metalworking is summarised in Table 5:4. The enclosure ditch contained three substantial deposits of metalworking debris (presumed dumps) in sectors to the east, south-west, and west, and a dump of kiln debris in the north-east sector. The metalworking debris includes approximately 5000 fragments of crucibles, 3000 fragments of clay investment moulds, a large quantity of ferrous slag, some evidence for wrought copper alloy working, and a number of metalworking tools and implements. There is also a large amount of hearth matrix, charcoal, and fuel ash slag which may have been from metalworking or from another 'industrial' processes.

The dump from the east sector of the ditch comprises almost solely crucible fragments of which four main types have so far been distinguished: small and large triangular-, dish-, rounded-, and bag-shaped crucibles. No mould fragments, metallic waste, or tools were recovered with this deposit. Further analysis of the crucible fragments may reveal the purpose of the different types of crucibles and their relationship with the founding and other metalworking processes.

Table 5:4. Summary of metalworking evidence from Weelsby Avenue

	E ditch	W ditch	SW ditch and F38
Crucible fragments	yes	yes	yes
Investment mould fragments	-	yes	yes
Bone implements	-	2	6
Copper alloy rods and implements	-	2	6
?Ingot mould	-	-	1
Iron smithing slag	-	yes	yes
Ferrous metalworking tools	-	chisel, punch	punch, 5 files
Lead ?coin weights	-	-	2
Whetstones		1	2

The dumps from the west and south-west sectors of the ditch, together with material from associated feature F38, include fragments of clay investment moulds, amongst which, moulds for terrets, three-link bridle bits, and linch-pin terminals have been recognised though chariot and harness fittings were probably not the only products. A few moulds were possibly for casting copper alloy components on to iron shanks. Copper alloy waste metal is attached to a number of the moulds, and there is a small amount of other copper alloy waste metal (droplets, fused metal, and slag or dross). The crucible fragments from these two dumps are of the small triangular type.

Other finds which may have been associated with founding include a number of bone artifacts, eight of which may have been implements for making the wax models for *cire perdue* casting (two shown on the right in Plate VIb), others may have been tools such as punches (Plate VI, lower centre). Although two of the bone artifacts are merely parts of handles, they reveal the fractured-off remains of slender shafts (Plate VI, one shown upper centre). Furthermore, the bone implements retain well-preserved tool marks from manufacture, either from whittling or from filing.

The evidence for wrought copper alloy working comes from an incomplete clay possible ingot mould and eight copper alloy rods. Some of the copper alloy rods may be part-manufactured items, but at least three are finished artifacts and may have been modelling implements (Plate VI, three on the left). The pottery from Weelsby Avenue is mostly locally made undecorated coarse ware, though decorated fine wares were imported during Phase 3. The bone implements and possible copper alloy implements are therefore unlikely to have been used for decorating pottery, and a wax-modelling function seems more probable.

The west and south-west dumps also include much ferrous slag, some certainly from smithing, and approximately 100 iron artifacts. These are mostly fragments of sheet and strip (some coated with copper alloy), but there are eight tools, and fragments of other artifacts.

The ferrous tools recovered from these two dumps are a chisel (No. 105), five files (Nos 121, 122, 144, 151, 157), a punch (No. 179), and a chisel or punch (No. 204). The chisel No. 105 is very possibly a hot chisel, whereas No. 204 and punch No. 179 are tools for working cold metal. Four of the files are finely cut; No. 144 has copper alloy inclusions embedded in the cuts (p. 160-1). The fifth file (No. 122) is more coarsely cut and made of unhardened iron (S49), which suggests that it was for working soft materials. This file also has copper alloy inclusions in the cuts, and although the possibility exists that these were derived from scrapings of metal present in the deposits of debris, it may be that the file had been used to work metal as well as possibly organic materials (e.g. bone implements), or indeed that it was intended principally for working soft metals.

Stratigraphic and ceramic evidence suggest that the three dumps of metalworking debris were roughly contemporary, probably deposited over a period of approximately ten years. The ceramic evidence, together with two possible coin weights conceivably for testing imported gold staters, has led the excavator to propose a mid-first century BC date for this metalworking activity. Imported decorated pottery occurs for the first time in contexts contemporary with the metalworking debris, and this might suggest a change in the nature of the settlement around this date. Its position near the coast may have made it a suitable site for the trading of products.

5.2.3. Glastonbury, Somerset

Glastonbury 'lake village', excavated almost in its entirety between 1892 and 1907 by A. Bulleid and H. St. George Gray, was interpreted as a defended crannog-like settlement built on a substantial timber substructure in the marshy lake (Bulleid and Gray 1911; 1917). Within the surrounding palisade were some ninety mounds, at least sixty-one of which were considered to have been houses containing sequences of clay floors, with the remaining areas of the settlement perhaps devoted to other activities.

Based on Bulleid and Gray's data, the settlement has been subject to re-interpretation on a number of occasions (e.g. Tratman 1970; Clarke 1972). However, analysis has been hindered by inadequate stratigraphic information, which has prevented the sequencing of artifacts, and structural correlations being determined between the mounds. This problem is further exacerbated by post-depositional effects which have resulted from desiccation of the site (Orme *et al.* 1981; Barrett 1987). The site is interpreted by Coles (1987, 249) to have been a gigantic undefended 'crannog', capable of permanent occupation even during minor flooding, which was occupied from the second century BC into the first century AD with possibly some subsequent

Romano-British activity.

A fairly large quantity of 'industrial' debris was recovered from Glastonbury, though little was analysed at the time of publication with the purpose of determining the process. A number of metal artifacts were analysed; a bowl and a terminal were found to comprise unleaded tin-bronze (Bulleid and Gray 1911, 178, 245), and of seventeen artifacts and lumps of possible ore, thirteen were almost pure tin, and the rest almost pure lead (Bulleid and Gray 1911, 244-7).

The finds which seem likely to have been associated with metalworking are listed in Table 5:5, though it is possible that some of the debris included (e.g. hearth matrix) may have been derived from other processes, such as glass-working (cf. Henderson 1985).

The crucibles from Glastonbury are large and small varieties of triangular form. There are also some globular, and trough-shaped vessels, none of which show evidence of intensive heating, nor do they retain vitreous or metallic waste (Bulleid and Gray 1911, 300-3). Four were found near a 'furnace' in Mound 62, and others were found in association with triangular crucibles. In fact Bulleid and Gray recognised that these may not have been crucibles, though they were catalogued as such. Subsequent fabric analysis (Howard 1983, 386, table III.21.1) has shown that they are made of non-refractory clay and thus unlikely to have been for a high-temperature process such as melting bronze. Nevertheless, they may have been containers for other metalworking processes, for example for melting tin or lead. On the basis of the tuyères and moulded blocks of baked clay, Bulleid and Gray considered that Mound 5 and Mound 62 had contained furnaces

Table 5:5. Summary of metalworking evidence from Glastonbury

	Nos	Source
Crucible groups	*c.* 27	Bulleid & Gray 1911, 300-9*
Sprue-cup	1	Bulleid & Gray 1911, 308, D50*
Stone mould	1	Bulleid & Gray 1917, 624, S1
Tuyères/'furnace'	2	Bulleid & Gray 1911, 309
Copper alloy waste	7	Bulleid & Gray 1911, 238
Lead/tin lumps/ore	8	Bulleid & Gray 1911, 241-53
Ferrous slag	yes	Bulleid & Gray 1917, 363
Ferrous tools	10	Appendix A
Whetstones	*c.* 300	Bulleid & Gray 1917, 621-2

* Identity from Howard 1983, table III.12.1

(Bulleid and Gray 1911, 72, 143, 303, 309; 1917, 363). Clay investment moulds were not reported, though a sprue-cup has recently been identified by Howard (1983, table III.12.1). Ferrous slag was noted from some mounds but the exact location was not always specified (Bulleid and Gray 1917, 363).

Other artifacts which may just conceivably have had a metalworking function, but not included in Table 5:5, include:

(a) Three copper alloy tools (Bulleid and Gray 1911, 225, E75, E109, E140, pl. XLIII),
(b) Fourteen antler mallets (Bulleid and Gray 1917, 435-40, pls LXIV, LXV and LXVIII)
(c) Various antler and bone implements (e.g. Bulleid and Gray 1917, 412-3, 465)
(d) Smoothed lumps of 'red colouring matter' (Bulleid and Gray 1917, 624), possibly haematite.

Only the three copper alloy tools were attributed with a possible metalworking function by Bulleid and Gray. Some of the antler and bone implements may have had metalworking purposes such as decorating sheet metal or making models for *cire perdue* casting, or, as Bulleid and Gray (1917) suggested, may have been pottery decorating implements. The possible haematite may have been used as a polishing agent to finish metalwork.

The distribution of ferrous tools and the debris most likely to be from metalworking is shown in Figure 5:5. Three concentrations of tools and debris are identified:

(1) To the east, within a 35m area centred on Mound 44: a hot chisel (No. 101), a file (No. 146), a stone mould, triangular crucible fragments, and fused copper alloy. Other metalworking debris, and a further file (No. 129) occur 35m to the south-west of this area.
(2) To the south, within a 15m area centred on Mound 5: a file (No. 147), a 'furnace', triangular crucible fragments, and ferrous slag.
(3) To the north-west, within a 30m area centred on Mounds 74 and 75: a hot chisel (No. 92), three files (Nos 130, 133, 161), triangular crucible fragments, a sprue-cup, pieces of copper alloy waste, ferrous slag (probably a smithing hearth bottom), and nearby, a hammer (No. 84), a file (No. 118), a 'furnace', and copper alloy dross are from the area of Mound 62 within 5m of each other.

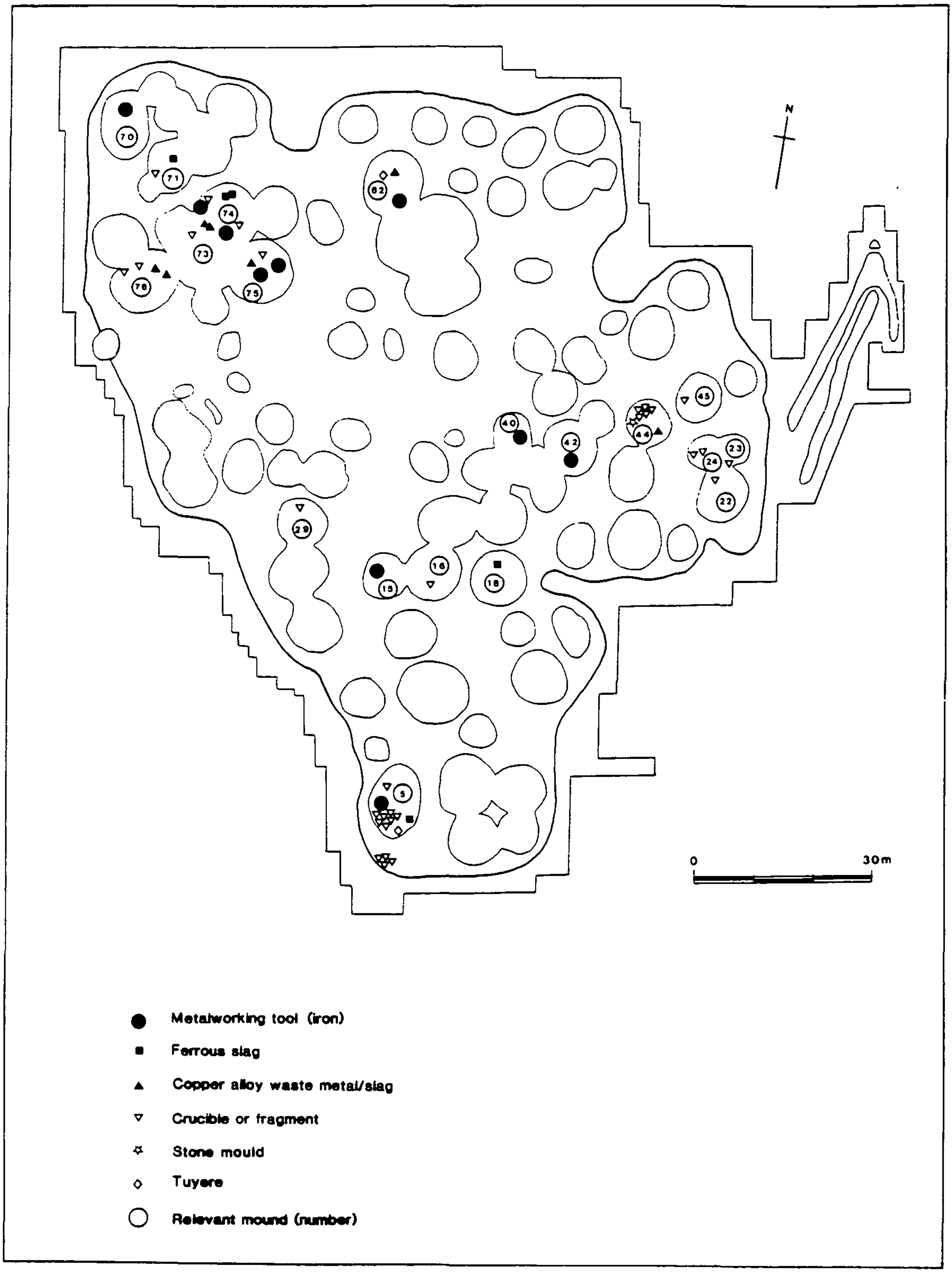


Figure 5:5 Glastonbury: distribution of metalworking debris and tools

Plan after Bulleid and Gray 1911, fig. 3

No stratigraphic relationships can be determined between the tools and the debris in these three areas; some of the finds were recovered away from the clay 'floors', and in other cases their exact positions are not recorded (cf. Barrett 1987). Nevertheless, the hammer (No. 84), a chisel (No. 92), and three files (Nos 130, 146, 161) were under, or stratified within the clay 'floors' of mounds.

The distribution suggests that there were three main areas which may have been used for metalworking during some stage of occupation, each area perhaps involving more than one metalworking process, though the processes need not have been concurrent. It may be significant that iron saws (i.e. possible bone-working tools) and iron gouges (woodworking tools) were concentrated in the north-north-west of the settlement away from the areas with metalworking evidence, whereas the copper alloy tools, antler mallets and modelling implements, and the possible haematite tended to be concentrated in the same three areas as the metalworking debris and tools. Although this does not necessarily relate the latter artifacts with metalworking, it does support the possibility that they were connected, and that at least three areas of the settlement were used for manufacturing purposes. (The three areas are encompassed in Clarke's model for Glastonbury (Clarke 1972, 814-9), within his 'major house pairs' and 'workshop huts'.)

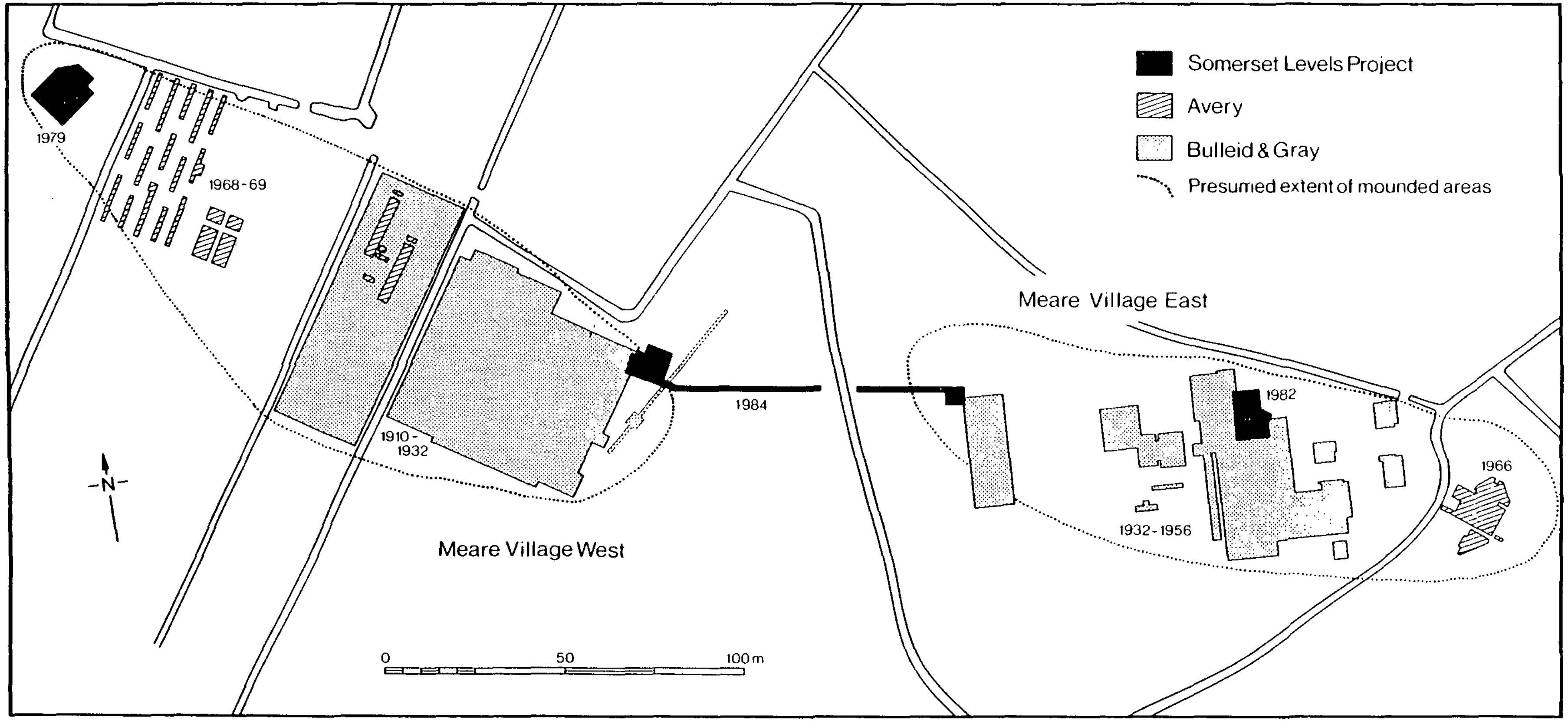
The indications are that Glastonbury, and also the Meare villages discussed below, served as major later Iron Age 'industrial' complexes with a variety of different manufacturing activities (Bulleid and Gray 1911; 1917; Clarke 1972; Orme *et al.* 1981; Henderson 1985; Coles 1987; Northover 1988).

5.2.4. Meare Village West, Somerset

The two settlements at Meare (Fig. 5:6), Meare Village West, and Meare Village East (Section 5.2.5), lie on two areas of raised bog only 200m apart, separated by marshy ground. There appears to have been no physical connection between the two (Coles 1987, 249). The eastern half of Meare Village West, excavated by A. Bulleid and H. St. George Gray between 1910 and 1933, was found to comprise forty mounds formed of clay 'floors' built on a timber sub-structure, but without a palisade (Bulleid and Gray 1948; Gray and Bulleid 1953; Gray 1966).

More recently, M. Avery sampled areas to the west of the centre of the settlement, but this work has never been fully published.

Figure 5:6 Meare villages East and West: map showing the location and extent of the excavated areas



Source and date of excavations carried out between 1910 and 1984. Reproduced from Coles 1987, fig. 1.2.

During 1979, the Somerset Levels Project under the direction of J. Coles excavated in the extreme west of the settlement, primarily to obtain environmental and dating evidence (Orme *et al.* 1981). From samples taken for radiocarbon dating and dendrochronology, together with the material evidence from the earlier excavations, Coles suggests that the settlement commenced in or around the third century BC and was abandonment in the first century AD (Coles 1987, 246-8). Occupation may have been intermittent, and there was possibly some limited Romano-British activity.

The debris and tools which seem likely to have been connected with metalworking are summarised in Table 5:6. Crucibles are small and large varieties of triangular form, of which the greatest concentration of sherds was in Mound 26 (Gray and Bulleid 1953, 257). Several crucibles were noted to have copper alloy waste metal attached; of the two analysed, both showed only traces of copper (Gray and Bulleid 1953, 255). Five fragments of carved stone blocks, three of which showed evidence for burning, may have been moulds for casting either ingots or objects (Gray 1966, 371-2, s21, s27, s28, s34, and s39). Clay moulds were not reported. Metal residues include some twenty or more pieces of both ferrous slag (Bulleid and Gray 1953, 248) and of copper alloy slag or waste metal (Bulleid and Gray 1953, 229-31, E7, E13, E17, E166, and E187), and about ten pieces of fused lead and lead ore/galena (Bulleid and Gray 1953, 250-2).

Implements which may conceivably have been connected with metal working include three copper alloy tools which could have been used

Table 5:6. Summary of metalworking evidence from Meare Village West

	Nos	Source
Crucible groups	*c.* 49	Gray & Bulleid 1953, 253-8*
Stone moulds	5	Gray 1966, 371-2
Tuyère & ?hearth	2	Gray & Bulleid 1953, 256, C15, 269, D12*
Copper alloy waste	yes	Gray & Bulleid 1953, 229-31; Orme *et al.* 1981, 60
Lead lumps/ore	c.10	Gray & Bulleid 1953, 250-2
Ferrous slag	yes	Gray & Bulleid 1953, 248
Ferrous tools	12	Appendix A
Whetstones	751	Gray 1966, 371, 376

* Identity from Howard 1983, table III.11.1

for modelling wax (Gray and Bulleid 1953, 220-221, E9, E33, and E152), and bone and antler modelling implements and burnishers (Gray 1966, 303, 343). There are also two hooked iron blocks, described as earth anvils (Gray and Bulleid 1953, 244, I28 and I32), discussed in Chapter 3.4. The Meare examples show no signs of wear.

The distribution of the ferrous metalworking tools and the debris is shown in Figure 5:7. Some clusters of tools and metalworking debris are apparent, though in general they are broadly spread:

(1) Mounds 33 and 39: a file (No. 134), crucible fragments, copper alloy waste, and ferrous slag.
(2) Area of Mounds 21, 24 and 38: a chisel (No. 111), a file (No. 158), and a punch (No. 187) occur within 10m, and nearby is a poker (No. 24), a chisel (No. 206), a stone mould, crucible sherds, copper alloy waste, and ferrous slag.
(3) South of Mound 9: a file (No. 148), a punch (No. 200), and ?graver (No. 212) occur within 3m of each other, and four stone moulds, crucible fragments, copper alloy waste, and ferrous slag are to the north-east and south-west of the tools.
(4) Mound 13: a file (No. 150), crucible fragments, and ferrous slag.
(5) Mound 22: a poker (No. 18), a file (No. 159), crucible fragments, and ferrous slag occur within 8m, and there is a further concentration of crucible sherds from adjacent Mounds 26 and 29.

The possible metalworking tools in copper alloy, bone and antler mentioned earlier were also from these areas. The distribution shown in Figure 5:7 suggests several foci for metalworking activity, perhaps with different processes being carried-out at different times during the intermittent occupation. However, as at Glastonbury, stratigraphic information from Meare Village West is poor, and this prevents sequencing between the tools and debris. Only two of the tools, both files (Nos 148 and 150), were stratified within clay 'floors' of mounds. General mixing of artifacts within the site both during and post occupation is apparent (Orme *et al.* 1981, 68).

Unlike Glastonbury, few distinct ferrous tools for other crafts were found, though flint tools, and part-worked bone and antler tend also to be concentrated in the same regions as the metalworking debris and tools. In addition, the areas of Mounds 7, 9, 13, 21, 22, 33, 34

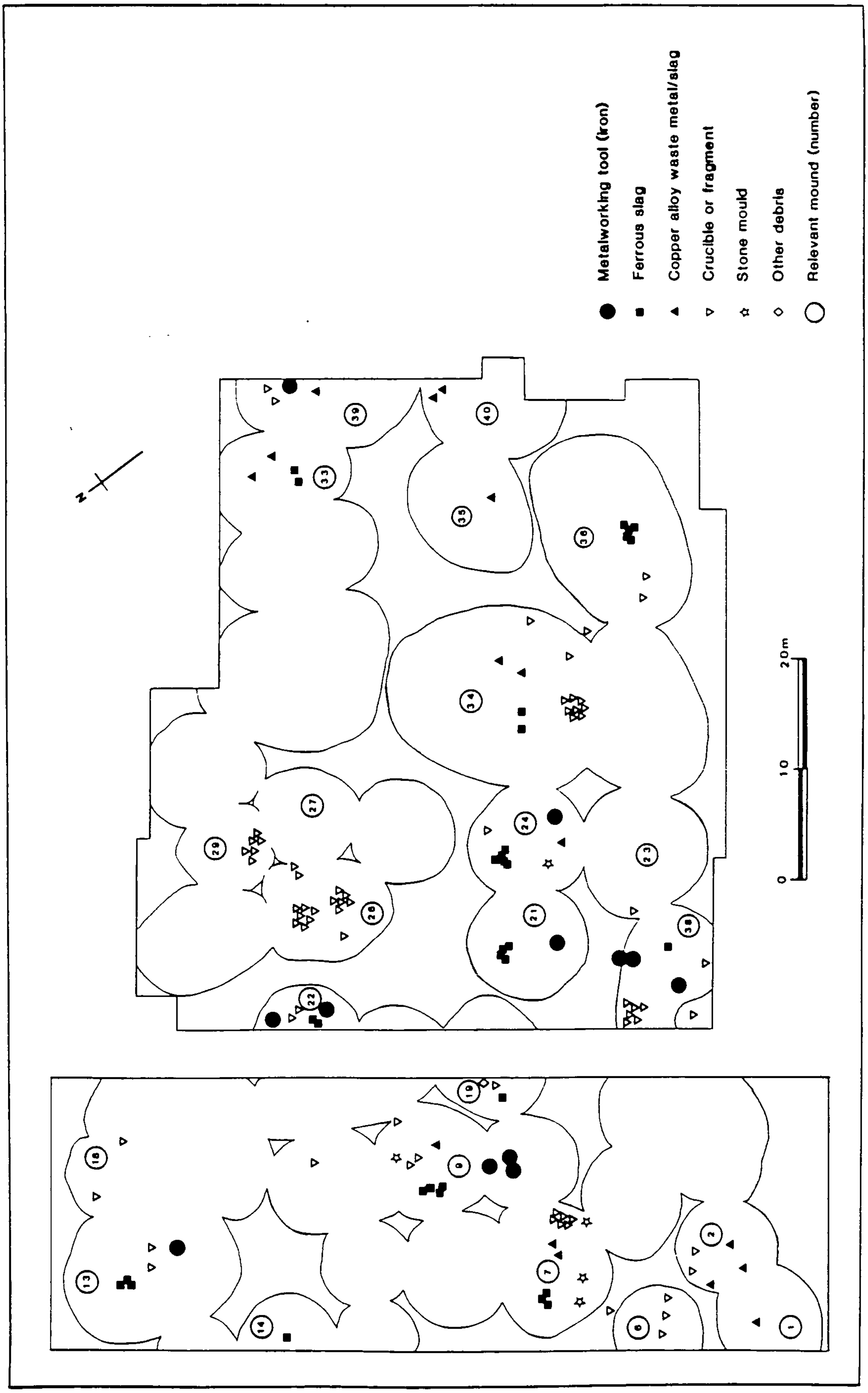


Figure 5:7 Meare Village West: distribution of metalworking debris and tools

Plan after Gray and Bulleid 1953, fig. 15

and 38 produced considerable numbers of finds of various types. The apparent clustering may therefore be due to the general mixing and trapping of artifacts in the peat and timberwork, but could also indicate that areas were set aside for manufacturing purposes during at least some periods of settlement.

5.2.5. Meare Village East, Somerset

Meare Village East (Fig. 5:6) was excavated by A. Bulleid and H. St. George Gray between 1933 and 1956, but not published until 1987 (Coles 1987). Fifty-one mounds were uncovered, constituting about a third of the settlement area. More recently, an area at the eastern end was investigated by M. Avery. Also, the Somerset Levels Project excavated an area adjacent to the excavations of Bulleid and Gray (Mounds 19 and G) and a trench between Meare Village East and Meare Village West (Orme *et al.* 1983; Coles 1987). The material evidence from all these excavations has been published together (Coles 1987).

Meare Village East was probably founded on dried peat, without the need for a sub-structure (Coles 1987, 249). Settlement commenced 50-100 years later than at Meare Village West, that is, in or around the second century BC. Occupation may have been intermittent, with final Iron Age abandonment in the first century AD, though there is evidence to suggest slight and intermittent occupation during the second to fourth centuries AD (Coles 1987). Similarities in the material remains at Meare Village East and Meare Village West suggest that the east village may possibly have been an 'off-shoot' of Meare Village West (Coles 1987, 249).

Only a small quantity of metalworking debris was recovered from Meare Village East. There are a few crucible fragments (Coles 1987, 61-2, C1-C5) and a tiny hemispherical heating tray, 20mm in diameter, which has copper, tin, and iron within the fabric (Coles 1987, 134-6, L10, fig. 3.58). Clay moulds and stone moulds were not reported. Only one piece of copper alloy slag and some possible fuel ash slag was found (Coles 1987, 62, C6). Ferrous slag was recorded only from Coles' excavation (Orme *et al.* 1983, 69; Coles 1987, 130, I82).

There are eight probable ferrous metalworking tools: two pokers (Nos 26 and 27), two anvils (Nos 48 and 52), a hot chisel (No. 99), two files (Nos 120 and 160), and a tracer or graver No. 189). Considering the smaller area excavated, these compare well with the numbers recognised from Meare West (twelve) and from Glastonbury (ten).

The finds which are likely to have been connected with metal-working are listed in Table 5:7.

The only other artifacts recovered which may conceivably have had a metalworking function are a copper alloy implement (Coles 1987, 73, E66.126, fig. 3.13), two or more antler mallets (Coles 1987, 89, 97, H5, H88, fig. 3.25), and a hooked iron block (Coles 1987, 123, I39, fig. 3.50).

The distribution of the metalworking tools and debris from Meare East is shown in Figure 5:8. It is worth noting that Mounds 10 and 30 each produced an anvil and a file within 5m of each other (Nos 52 and 120, and Nos 48 and 160, respectively) and from the latter mound, two crucible fragments were recovered.

Coles has plotted the distribution of the artifacts by material (Coles 1987, figs 7.2 - 7.6). Mounds 13, 17, and 22 show the densest population of finds, with metal finds concentrated also in the areas of Mounds 15, 19/20, and 30. Furthermore, he has analysed the stratification of artifact types (as far as is possible from the data of Bulleid and Gray) in an attempt to draw correlations between the chronological sequences of the mounds (Coles 1987, 242-4, tables 7.3 and 7.4). If the conclusions are correct, then amongst the metalworking tools, pokers No. 27 and anvil No. 52 may be from the earliest occupation of the site, whereas chisel No. 99 and file No. 120 may be from the latest Iron Age occupation. Anvil No. 48 and file No. 160 were from the lowest levels of Mound 30, but these cannot yet be sequenced. Poker No. 26 was unstratified from the area of Mound 14, and tracer or graver No. 189 was from the top of Mound 20.

Table 5:7. Summary of metalworking evidence from Meare Village East

	Nos	Source
Crucible fragments	5	Coles 1987, 61-2, C1-C5
Heating tray	1	Coles 1987,134-6, L10
Copper alloy slag	?	Coles 1987, 62, C6
Ferrous slag pieces	4	Coles 1987, 130, I82
Ferrous tools	8	Appendix A
Lead waste/ore	2	Coles 1987, 134-6
Whetstones	409	Coles 1987, 150-3

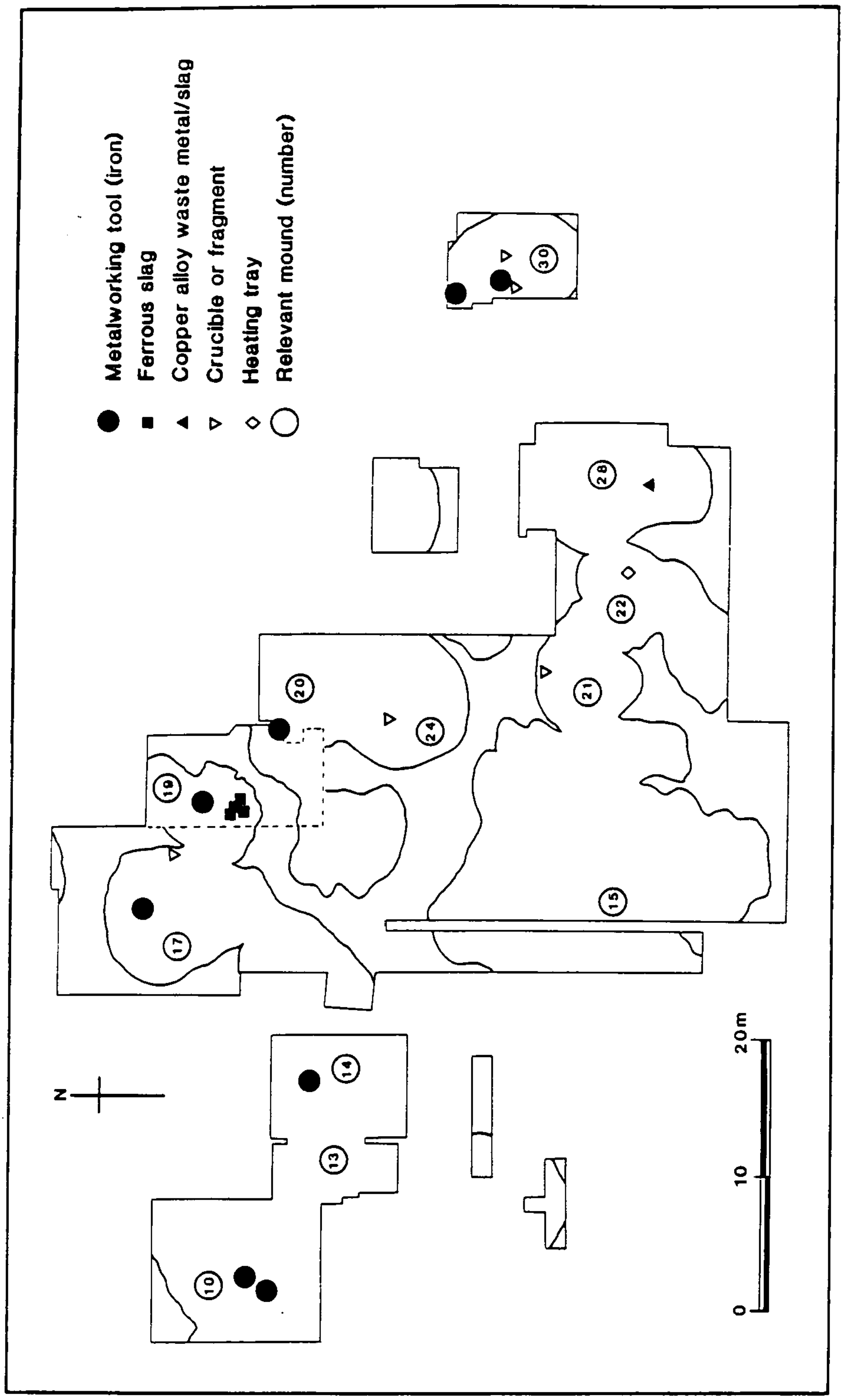


Figure 5:8 Meare Village East, central area: distribution of metalworking debris and tools

Plan after Coles 1987, fig. 7.1

5.2.6. Other key sites

The following six sites (a-f, below) have yielded evidence of metalworking, but few metalworking tools were recovered (South Cadbury, Beckford, Fison Way, Wetwang Slack), or the tools were from contexts unrelated to metalworking activity (Danebury), or were discovered during quarrying (Hunsbury). Of these sites, only the 1969-78 excavations at Danebury have been published, although at Hunsbury, the majority of the salvaged material has been described but interpretation is limited by lack of contextual information. Phasing, site interpretation and finds analysis from the other excavations has not been completed or published and it is possible that additional evidence for Iron Age metalworking will be determined or that dating will be refined. These six sites, therefore, are a selection of other key occupation sites where there are indications of metalworking and where metalworking tools have been found, but where few associations can be determined between the tools and the debris, and where full information is not yet available. Three are hillforts and three are lowland settlements (for a discussion of the types of sites subsumed by these terms see Cunliffe 1974; Harding 1974; Hingley 1984).

(a) Danebury, Hampshire

Danebury hillfort has been excavated seasonally over twenty years since 1969; site interpretation and the material evidence from the first ten years of excavation has been published (Cunliffe 1984b) and the subsequent excavations are shortly to be published (B. Cunliffe forthcoming). The correlated radiocarbon dates and pottery sequence, according to ceramic phase (cp) are: cp 3, 550-450 BC; cp 4-5, 450-400 BC; cp6, 400-300 BC; cp 7, 300-100/50 BC; cp 8, 100-10 BC; cp 9, 10 BC - 50 AD (Cunliffe 1984b, 197; cf. Cunliffe 1984a, fig. 2:1). Further refinement of the dates is expected (Cunliffe 1984b, 190-198, 549-50; see also Haselgrove 1986).

Only a limited amount of metalworking debris was recovered from the 1969-78 excavations. This comprises ferrous slag, four fragments of triangular crucibles, two possible tuyères and four fragments of possible bellows guards (Poole in Cunliffe 1984b, 406-7), all from cp 4-7 contexts, with the majority from cp 7 contexts. Analysis of the ferrous slag (Salter 1984, 433-7) has distinguished a high-density type which is probably smithing slag, and a low-density type containing both iron and copper, which is thought to have possibly been the lining from hearths used for both iron and non-ferrous metalworking. A possible iron bloom fragment (Sellwood 1984, 371, fig. 7.26) and a hoard of twenty-one sword-shaped currency bars (Sellwood 1984, 357-61, figs 7.15-7.18) may be further indicators of ironworking activity during cp 7. A hoard of scrap iron found in 1979 may be evidence for the recycling of iron (Cunliffe 1984b, 556), or at least for iron-smithing. Distribution plots (Salter 1984) of the metalworking debris show a greater quantity of debris south of the Iron Age road, but no concentration which would indicate a metalworking area (Salter 1984, 437, fig. 7.72).

Of the eight metalworking tools from the 1969-78 excavations which have been catalogued in the current study, a ?scorer/scriber (No. 219) is from a cp 5 context, and a punch (No. 183) is from a cp 6 context. The other six, file (No. 123), punch (No. 163), ?graver (No. 214), ?scribers (Nos 223 and 224), and ?burnisher (No. 231) are all from cp7 contexts. The published report does not provide sufficient contextural information to enable associations of these tools to be determined. From the more recent excavations there is an anvil (No. 51), a hammer (No. 60), a cold chisel (No. 109) and two punches (Nos 173 and 176), all from cp 6-7, or cp7 contexts. In addition, there are a number of other tanged tools, conceivably metalworking tools (e.g. nos 2.259, 2.264, 2.265 and 2.266, in B. Cunliffe forthcoming).

(b) Hunsbury, Northamptonshire

During nineteenth century quarrying for the clay ironstone at Hunsbury hillfort, a large quantity of pottery, metalwork, bone and other artifacts were salvaged. The few observations which were made at the time of discovery note about 300 densely concentrated pits, some dug to a depth of 3m and a few lined with stone (Fell 1936, 55-8; Knight 1984, 185-6). The bulk of the finds apparently came from these pits, but no details of their contexts were recorded.

A late fifth or fourth century BC date is indicated for the beginning of settlement on the basis of pottery and two imported brooches (Smith 1912, 428-9; Fell 1936, 95; Knight 1984, 81). Stylistically late metalwork (Smith 1912) and pottery suggest that occupation ceased by the end of the first century BC (Knight 1984, 99, 186) or possibly extended into the early first century AD (cf. Cunliffe 1974, 85-6, fig. A:21). Knight classifies Hunsbury in his 'Iron Age

2' period, with occupation (or at least intensive occupation) ceasing by the mid or late first century BC (Knight 1984, 99, 186, fig. 25).

'A considerable quantity of iron slag' (Fell 1936, 67, 95) was discovered at Hunsbury. Other metalworking debris includes a crucible with copper alloy residue (Fell 1936, 82, SP3) and a sandstone mould with a circular depression and a groove (Fell 1936, 73, no. 6). The metalworking tools comprise eight pokers (Nos 12, 13, 14, 16, 17, 19, 21, 25), two hammers (Nos 61 and 72), six hot chisels (Nos 91, 94, 100, 103, 104, 108), and a file (No. 119). Other artifacts possibly connected with metalworking are two whetstones (Fell 1936, 73, pl. XI A, 2), and conceivably an antler mallet (Fell 1936, 73, no. 17).

A small proportion of the artifacts in the Hunsbury assemblage may not be Iron Age, but could be casual losses from the Saxon and later occupation sites in the vicinity (W. Moore pers. comm.). With regard to the ironwork, one artifact appears technologically to be medieval or later and another is also unlikely to be Iron Age. Re-examination of the metal samples taken by Ehrenreich (1985) indicates, in the opinion of the present writer, that an artifact described as a ploughshare (Ehrenreich 1985, 180, HNY53a) had been made of cast iron and thus unlikely to be earlier than medieval. Another artifact, a spearhead (Ehrenreich 1985, 169, HNY19b), had been selectively carburized and quench-hardened, which tends to suggest a post-Roman date for this type of artifact. Agricultural implements and non-defensive weapons could easily have been lost during post-Iron Age activities at Hunsbury, and the presence of these two artifacts in the assemblage casts some doubts on the date of other items which are not typologically Iron Age. The readily available iron ore at Hunsbury was probably exploited throughout antiquity and ironworking tools may have been lost. Nevertheless, of the metalworking tools discovered at Hunsbury, the pokers and hammers are typologically Iron Age and the file is likely to be early. Only the chisels are not datable by form.

The quantity of tools and apparently also metalworking debris suggests that large-scale ironworking and at least some non-ferrous metalworking took place at Hunsbury. Possible hoarding of ironwork is suggested by two ploughshares found one inside the other (Fell 1936, 66, no. 12; Manning 1972, 231). The proximity of iron ore may have been an important factor in the siting and economy of the hillfort.

(c) South Cadbury, Somerset

Between 1966 and 1970, trenches were cut across the ramparts and selected areas of the centre of the hillfort (Alcock 1967; 1968; 1969; 1970). A further trench was cut across the rampart in 1973, and whereas this excavation has been published in full (Alcock 1980), the earlier excavations still await final publication.

Towards the centre of the hillfort, in an area (area 'N') which appeared to have had a non-domestic function, was a cluster of stone-lined and clay-lined hearths (Alcock 1970, 20, fig. 2). Scattered over this area, but close to the hearths, were a number of fragmentary copper alloy artifacts including parts of a decorated shield-boss dating stylistically to the first century BC or early first century AD (Spratling 1970a, 188-9, fig. 2; and cf. de Navarro 1972, 331), a plain shield mount, a twisted portion of a third mount, binding, and waste cast metal (Spratling 1970b, 1-13). From the same area of the hillfort were weapons and tools, which led the excavator to suggest that this may have been an armourer's workshop (Alcock 1970, 47).

At least two ferrous metalworking tools were found in this area, a chisel (No. 110) and a scriber (No. 222). The interim reports for the excavations also record an iron stake, and fragments of a copper alloy tracer and two other punches (Alcock 1970, 47, pl. VIII; Spratling 1970a, 190, fig. 3; Spratling 1970b, 13-14). However, it is difficult to sustain the identification of these four artifacts as metalworking tools, either on form (in the case of the stake), or because of the unsuitability of the copper alloy for the punches, and indeed Spratling himself has now retracted his earlier identification of these items as metalworking tools (Spratling 1972, 348).

There is also evidence for founding; fragments of small triangular crucibles and investment moulds were recovered from features across the site, but no concentrations are apparent, and none was from area 'N' (Howard 1983, 415).

From the 1973 excavation, an iron punch (No. 203) was found in a mid-first century AD layer (Cadbury phase 9B) of the Iron Age rampart (Alcock 1980, 673).

(d) Beckford, Hereford and Worcester

The extensive enclosed settlement at Beckford, occupied from about the third century BC into the Roman period, was excavated between 1972 and 1979 in advance of gravel-quarrying (Britnell 1974). In the west of the excavated area, on the slopes of Bredon Hill, was a rectangular enclosure from which a large quantity of Middle Iron Age foundry debris was recovered (J. Dinn pers. comm.).

Iron-smithing slag and foundry debris were also recovered from across the rest of the site, in both Middle Iron Age and Late Iron Age contexts (McDonnell 1986a, 150). The foundry debris includes fragments of investment moulds, amongst which a 'horn-cap' mould has been recognised (Hurst and Wills 1987). There is also hearth lining, numerous droplets and fragments of unleaded waste bronze, and at least forty-four fragments of crucibles of triangular and other forms which had been used for melting unleaded bronze (Linton and Bayley 1982a). The non-ferrous metal debris was concentrated in four chronologically distinct areas of the settlement (Northover 1988).

An iron poker (No. 23) was found in a Middle Iron Age pit in the west enclosure where the greatest quantity of foundry debris was concentrated. No other metalworking tools have been recognised, though a number of incomplete and fragmented iron rods, which may have been metalworking tools, were recovered from features away from the west enclosure (two from MIA contexts, six from LIA contexts).

(e) Fison Way (Gallows Hill), Thetford, Norfolk

Fison Way, excavated 1980-1982 (Gregory 1981; forthcoming), is a large enclosed complex of an unusual nature, possibly with ritual functions (C. Haselgrove pers. comm.). The site yielded a large quantity of metalworking debris comprising complete and fragmentary triangular crucibles in three different sizes, hearth lining, fragments of 'coin pellet moulds', a few small fragments of investment moulds, and two fragments of possible ingots of bronze (Linton and Bayley 1982b). X-ray fluorescence analysis (Linton and Bayley 1982b) indicates:

(1) Copper in some of the hearth lining
(2) Bronze in crucibles, hearth lining, 'coin pellet moulds' and investment moulds
(3) Leaded bronze in crucibles and 'coin pellet moulds'
(4) Silver in a single fragment of 'coin pellet mould'.

It has been suggested (Linton and Bayley 1982b) that bronze was probably the main metal species being worked, though leaded bronze, and silver coins may also have been produced. The majority of the metalworking debris was concentrated in three areas of the site and is considered to have been deposited probably during the first half of the first century AD, though some may date to the immediate post-Conquest years (T. Gregory pers. comm.).

The only tool from Iron Age levels which may possibly have had a metalworking function, a punch (No. 178), was not associated with any of the concentrations of metalworking debris. There are also a few fragmentary iron rods, possibly parts of tools, and these were also unassociated with any metalworking debris. In addition, there are numerous unstratified small tools which were found by metal detectors.

(f) Wetwang Slack settlement, North Humberside

The Wetwang Slack settlement is adjacent to Wetwang Slack cemetery - the continuation westwards of the Garton Slack cemetery (Dent 1982, fig. 10). The cemeteries and associated settlement complexes (see also Section 5.4.a) were excavated in advance of gravel-quarrying by Brewster until 1975 (Brewster 1975; 1980), and subsequently by Dent (1978; 1982).

The earliest (unenclosed) settlement at Wetwang Slack commenced around the fourth century BC (Dent 1982). Excavation during 1979 of a small area of the settlement, 0.4km north of the cemetery, indicated a long series of structural phases of Iron Age occupation, and enclosure during the later stages. Abandonment was probably during the second century AD.

The 1979 excavation yielded founding and iron-smithing debris from features away from the immediate vicinity of the Iron Age round-houses, in areas with continuity of occupation into the Roman period (J. Dent pers. comm.). The debris was associated with Iron Age artifacts such as pottery and weaving combs, though the presence of brass in a fragment of a circular crucible (Wilthew 1986) suggests that at least some of the metalworking debris may be Roman.

The non-ferrous metal debris which is probably residual from the Iron Age occupation includes two triangular crucible fragments, and a few fragments of investment moulds amongst which, moulds for a terret, a linch-pin, a possible horse-harness fitting and a pendant have been recognised (J. Dent pers. comm.). A bone modelling implement was also found.

Individual pieces of iron-smithing slag were recovered from across the excavated area, but there was also an accumulation in the boundary ditch (which also yielded one of the triangular crucible fragments). This slag concentration was close to a four-post structure which contained a possible hearth, and it has been suggested (McDonnell 1986b) that this may have been a smithing area. Four iron tools, a file (No. 124), two punches (Nos 185 and 205) and a possible graver (No. 211), were also recovered from features which included residual Iron Age material, though they cannot be definitely associated with the Iron Age metalworking activity.

5.3. Occurrence of tools and metalworking debris at occupation sites

This Section examines the occurrence of metalworking debris at occupation sites, the occurrence of tools with debris, and possible associations of tools and debris.

5.3.1. Metalworking areas

Tools, and debris from the manufacture of artifacts, have seldom been recovered in association with a hearth or features which suggest a metalworking area. Raised smithing hearths are unlikely to survive (McDonnell 1983, 81) and this may contribute to the paucity of evidence for metalworking areas. On the other hand, iron-smelting furnaces were generally set on or into the ground, and the remains of furnace bases with smelting slag *in situ* have not infrequently been recognised (e.g. Tylecote 1986, 136-141; Crew 1987; 1989). Moreover, smelting produces considerable quantities of slag, which sometimes may be readily determined morphologically especially if tapped from a furnace.

Iron tools were unlikely to have been used during iron-smelting except perhaps to rake the slag. Stone anvils and hammers, presumably for the preliminary forging of the bloom, have occasionally been found at iron-smelting sites (p. 16 and p. 95). Hearth tools seem more likely to have been required during the smelting of non-ferrous ores, but as indicated earlier, there is very little evidence from Britain of the extraction of non-ferrous metals, and at none of the possible sites have tools been found. In this Section (5.3), therefore, the occurrences of metalworking debris and tools discussed relate principally to the main manufacturing processes of iron-smithing, non-ferrous wrought working and founding, and coin production.

Of the sites discussed in Section 5.2, possible metalworking areas are suggested by:

(1) Weelsby Avenue: sub-enclosure, dumps of debris, tools
(2) Glastonbury: hearths with tuyères, ?associated debris and tools
(3) Meare West: hearths, ?associated metalworking debris and tools
(4) Beckford: foundry debris within a sub-enclosure
(5) Wetwang Slack: possible hearth within a four-post structure
(6) South Cadbury: group of hearths, scrap metal, tools.

Both iron and non-ferrous metals were certainly worked at the first five sites listed above, however there is no clear evidence that these metals were worked at the same areas of the sites. At Beckford and at Wetwang Slack there are indications that separate metalworking areas were employed for iron-smithing and for founding, at least during some period of occupation.

A number of other sites have produced evidence of metalworking areas (excluding smelting), listed in Table 5:8. None of these fourteen sites appear to have yielded any iron tools associated with the metalworking debris, though at Bigbury, the tentative identification of the temporary smithy is based principally on the *in situ* anvil despite no metalworking debris being recorded.

Of the twenty (and maybe more) sites where probable and possible metalworking areas have been identified (Section 5.2 and Table 5:8), three sites at least seem to have had working areas which were used for working both iron and copper alloys (Maiden Castle, The Breiddin, Llyn Bryn Dinas), whereas at the other sites, metalworking areas seem to have been devoted to the working of a single metal species. However, since the data is based sometimes on only a small quantity of debris the absence of certain residues need not imply that other processes were not carried out at these metalworking areas.

Ferrous metalworking tools have been recognised at eleven of these twenty sites, but only at South Cadbury and Weelsby Avenue (plus Bigbury) were tools found adjacent to the metalworking area, or the stratigraphy adequate to associate the tools with the hearths with any certainty. Compare Clarke's 'tool-chest' hypothesis for Glastonbury (Clarke 1972, 814, but cf. Barrett 1987). Stone metalworking tools occur at a further three sites, but only *in situ* at Kestor.

Although there is no certain evidence for the siting of the metalworking areas at Gussage All Saints, it seems likely from the distribution of the metalworking debris (Section 5.2.1) that the principal working areas were located within the settlement and close to the entrance. At Bredon Hill, St. Mawgan-in-Pyder, and Weelsby Avenue, metalworking areas were found near the entrances, whereas at Maiden Castle (Dorset), a working area was beyond the east entrance, and at Wakerley, both iron smithing and smelting occurred outside the enclosure but well away from the entrance. To some extent the finding of metalworking areas at or beyond entrances often reflects trends in excavation, but at other sites, possible metalworking areas have been found well within the occupation areas (e.g. Hengistbury Head, South Cadbury, Glastonbury, and the Meare villages). Iron was also smelted inside occupation sites, for example near to the maintained entrance at Gussage All Saints (Wainwright 1979, 25, 32, fig. 24), opposite the entrance and adjacent to the palisade at West Brandon (Jobey 1962, 19-21, figs 6 and 7), and well within the settlements at Kestor (Fox

Table 5:8 Evidence for possible metalworking areas (excluding smelting) at other sites. (Sites not discussed in Section 5.2)

Site	Process	Evidence	Probable date	Source
Bigbury	?iron-smithing	F Ti	C2nd BC	Thompson 1983
Bredon Hill	Cu alloys	H S	C1st BC	Hencken 1938
The Breiddin	iron, Cu alloys	H O S	C8-6th BC*	Thorburn 1988
Bryn y Castell	iron-smithing	C H F S Ts	C5th-3rd BC*	Crew 1987; 1988b
Crawcwellt	iron-smithing	C F S Ts	LIA	Crew 1989
Hengistbury Head	Cu/Ag/Au, refining, ?coins	A H O S	LIA, LIA/R	Bush-Fox 1915; Gowland 1915; Northover 1987; 1988; Salter 1987
Kestor	?smithing	C Ts	> 400 BC	Fox 1954
Llanmynech	Cu ?refining	C H S	C2nd BC - C1st AD*	Musson and Northover 1989
Llyn Bryn Dinas	iron, Cu alloys	H S O	C3rd-1st BC*	Thornburn 1988
Maiden Castle	iron-smithing composites	C S A	mid C1st AD "	Wheeler 1943, 377 Northover 1988
Merthyr Mawr Warren	iron, Cu alloys	H S	?early-mid IA	Fox 1927
Roxby	iron-smithing	H S	mid C1st AD	Inman et al. 1985
St. Mawgan in Pyder	Cu alloys	A H O	C1st BC	Threipland 1956
Wakerley	iron-smithing	H S	LIA	Jackson & Ambrose 1978

* Uncalibrated radiocarbon spread; A, artifacts; C, charcoal/ash; H, hearth; F, other structural feature; S, slag/dross/hammerscale; O, other; Ti, tool (iron); Ts, tool (stone)

1954, 38-40, figs 7 and 9) and Roxby (Inman *et al.* 1985, 200-204, fig. 12). Thus, although there may be a bias towards features which are excavated (or surveyed), there nevertheless appears to have been no particular recognisable preference for the siting of these potentially polluting activities (cf. Sharples 1987, 508), nor to relegate metal-working away from occupation areas.

5.3.2. Secondary deposits

Commonly, metalworking debris has occurred in secondary contexts, sometimes as deposits in a pit or boundary ditch comprising residues from more than one process, for example at Gussage All Saints and Weelsby Avenue, or from a single process as in the case of the iron-smithing slag at Wetwang Slack. Frequently, debris has been recovered as a single or small number of finds, either in occupation levels with no apparent metalworking connections, for example at Little Waltham, Essex (Drury 1978) and Winklebury Camp, Hampshire (Smith 1977), or occasionally in the make-up of features such as ramparts, for instance at Castle Yard, Farthingstone (Knight 1988).

Although no hearths survived at either Gussage All Saints or Weelsby Avenue, these two sites are unusual in the quantity of debris yielded, the greater proportion of which occurred as discrete deposits. These deposits are presumably dumps of debris deposited away from the immediate metalworking areas, and constituting therefore *secondary refuse* (cf. Schiffer 1976). Both sites also yielded numerous metalworking tools intimately mixed with the metalworking debris.

Other tools have occurred in possible dumps of metalworking debris. At Casterley Camp, a hammer (No. 64) was found with ashes and iron slag at the bottom of a ditch (Cunnington 1913, 103). Although a temporary working area may be indicated by this group, dumping of debris seems more likely. At Castle Yard, Farthingstone, a poker (No. 20) was found with 'several hundreds-weight of scoria of iron' and charcoal within the core of the rampart during nineteenth century levelling operations (Knight 1988, 33). At least some of the slag was tapped smelting slag (McDonnell in Knight 1988, 37-9), but since only three pieces had been retained, the nature of the bulk of the slag cannot now be determined. It seems unlikely that this short poker was connected with smelting, which tends to suggest that there was concurrent iron-smithing (or other metalworking activity) at Castle Yard.

Where tools have occurred in dumps of debris, the simplest explanation is that they had been lost during clearances of metalworking areas or had been discarded if damaged beyond repair. It is conceivable that some apparently discrete deposits could have derived from the burning down of working areas, although this seems unlikely considering the types of features or the stratigraphy where these deposits have been found. Moreover, any of the tools associated with debris could have had symbolic associations (Section 5.7.4), as may the debris itself (cf. Needham and Sørensen 1988, 125).

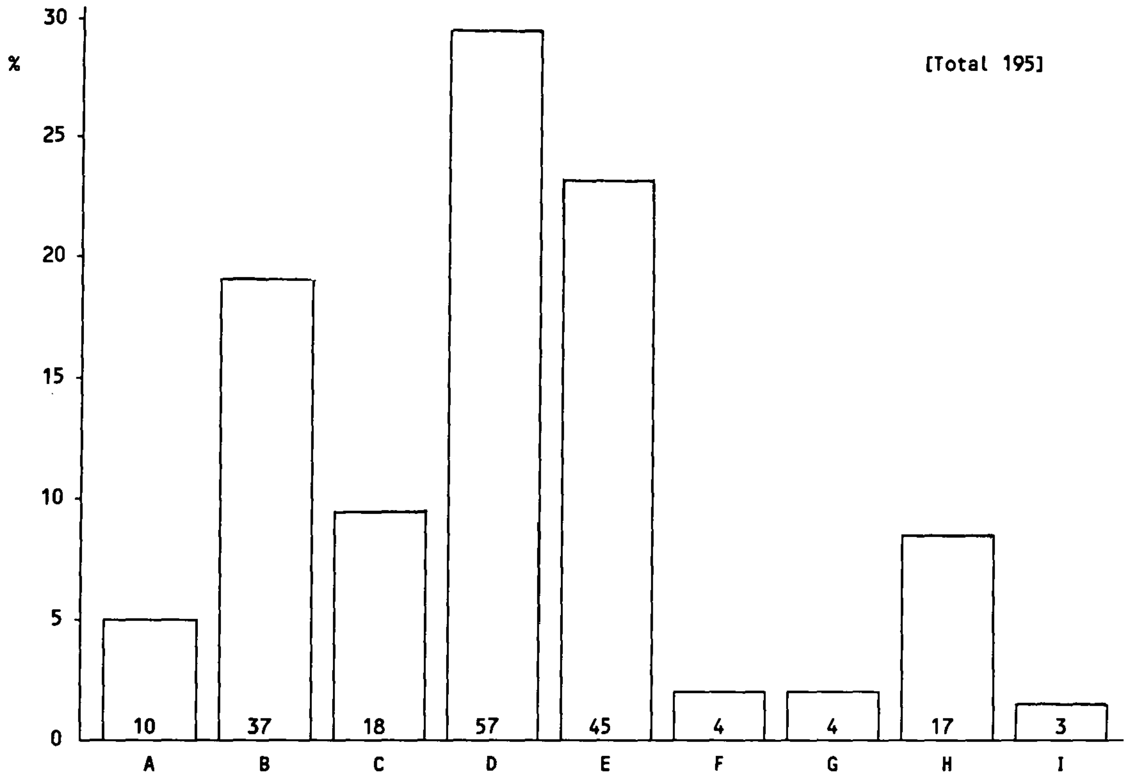
5.3.3. Frequency of tools with metalworking debris

Figure 5:9 shows the frequency of metalworking tools according to possible metalworking connections. It is recognised that a small proportion of the tools may be incorrectly attributed to a metalworking function, and in addition that Nos 154 and 155 may have been part of the same artifact (see above, p. 138), and therefore the tool population shown in Fig. 5:9 (and also in Figs 5:11, 5:13 and 5:15 below) may be marginally distorted.

Although only 5% of the tools occur in probable and possible metalworking areas, 19% occur in metalworking dumps, and a further 9% have other possible connections with metalworking debris. The latter, however, cannot all be demonstrated to be associated or even contemporary since the data available does not always enable archaeological relationships to be established.

Tools without apparent metalworking connections occur in domestic contexts (e.g. Bredon Hill, Danebury), refuse pits (e.g. Caburn, Danebury, Oare, Southcote), within or under grain storage pits (Worthy Down, Garton Slack), beneath floors (Madmarston), in post-holes (Midsummer Hill), ramparts (South Cadbury), ditches (Billingborough), and in destruction levels (Bredon Hill, Mynydd Bychan). A number of these tools may have been casual losses, though in a few cases intentional deposition is indicated (Sections 5.4 and 5.7.4, below). Some tools may have been used for other purposes at their time of deposition, for example two hammers found in the massacre levels at the inner gateway at Bredon Hill were considered by the excavator to have been carried as defensive implements (Hencken 1938, 24).

The proportion of tools with unknown associations is potentially 32% (Fig. 5:9, groups E and H), and these include discoveries such as



A Possible metalworking areas

B Discrete deposit(s) of metalworking debris (probable dumps)

C Other connections with metalworking debris

D Metalworking activity at the site but tool(s) unconnected with metalworking debris

E Metalworking activity at the site but associations not known

F From sites with no metalworking debris

G From excavated 'hoards' (possible concealments etc)

H Discoveries: no metalworking debris known from the site

I Possible burial(s) within occupation sites

Figure 5:9 Frequency of metalworking tools at Iron Age occupation sites (%)

the large assemblage from Hunsbury, other unstratified finds for which an Iron Age date is likely, tools for which a precise context is not stated in the excavation report, and a few unpublished finds. Single tools were found at Rainsborough Camp, Groundwell Farm, Southcote, and Tre'r Ceiri, but the apparent absence of metalworking debris need not exclude the tools from having had a metalworking function. Only a small quantity of debris has been reported from Hod Hill, and since the only mention of iron slag occurs in a soil report (Dorell and Cornwall in Brailsford 1964, 133-5), this tends to suggest that 'industrial' connections were not sought at this site.

Table 5:9 summarises the evidence for metalworking, excluding smelting, at Iron Age occupation sites which have yielded ferrous metalworking tools. Phasing, site interpretation and finds analysis have not yet been completed for some excavations listed and it is possible that additional evidence for Iron Age metalworking will be established in the future.

As indicated previously, it is often difficult to determine the process by which some metalworking residues were derived. Analysis of debris has sometimes identified the metallic and vitreous phases and thus determined the metalworking process involved. In other cases the results of analysis have not been clear-cut, particularly with ferrous slags. Many of the residues shown in Table 5:9, particularly those from less recent excavations have not been scientifically analysed and may therefore be incorrectly attributed (uncertainties are noted). In addition, some vitreous residues (fuel ash slag) are non-diagnostic of high temperature processes (cf. Evans and Tylecote 1967; Biek 1970), and mistaken identifications may occur with other materials, (e.g. daub and clay moulds; mineralised artifacts, iron nodules, panning). Moreover, modern excavation techniques contribute to a higher level of retrieval and recording. At Bryn y Castell, ironworking residues recovered by flotation account for 40% (300kg) of the total weight of slag, suggesting that iron production can be considerably under estimated if small-scale residues are ignored (Crew 1988b).

5.3.4. Sites with metalworking activity from which no ferrous metalworking tools have been recognised

Table 5:10 lists the metalworking debris from manufacturing processes from a number of sites (or from rubbish areas from presumed adjacent

Table 5:9 Occurrence of metalworking debris at Iron Age occupation sites where ferrous metalworking tools are present

Site	Iron-smithing			Non-ferrous metalworking								Iron tools			Implements
	hearth, lining, or tuyère	slag	bloom, blank or waste*	ingot mould	ingot, billet, or part-made	wrought scrap*	hearth, lining, or tuyère	waste metal, or slag/dross	crucible or sherds	lost-wax mould fragment	'coin pellet' mould	tongs, or poker	forming	finishing or decorating	B: bone W: whetstone T: touchstone
Bagendon	?	[+]	-	-	-	[+]	-	-	[1]	-	+°	-	[1]	[1]	T?
Barbury Castle													2	5	
Beckford		+					+	+	>44	+	-	1	-	-	W
Bigbury	-	-	-	-	-	-	-	-	-	-	-	-	5	-	W
Billingborough	-	+	-	-	-	-	-	-	-	-	-	1	-	-	-
Bredon Hill	-	-	-	-	-	-	-	+	-	-	-	-	5	-	B?
The Breiddin		(+)					(+)	+	+	+	-	-	-	[1]	-
Bulbury													2		
The Caburn	-	(+)	-	-	-	-	-	+	+	-	-	-	1	-	-
Casterley Camp	-	(+)	-	-	-	-	-	-	-	-	-	-	1	-	-
Castle Yard	-	(+)	-	-	-	-	-	-	-	-	-	1	-	-	-
Conderton Camp		(+)										1	-	-	
Croft Ambrey	-	+	-	-	1	-	-	+	+	-	-	-	-	2	W
Danebury	?	+	1	-	-	-	?	-	4	-	-	-	4	9	W
Dragonby		+					+	+	+	+	-	-	1	-	
Fison Way, Thetford					2		+		+	+	+°	-	-	1	
Garton Slack	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
Glastonbury	?	+	-	1	-	-	?	+	+	-	-	0	3	7	B? W
Groundwell Farm	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Gussage All Saints	+	+	+	-	2	+	+	+	c.600	7380	-	-	6	33	B W
Ham Hill		(+)	[+]						+			-	[4]	[2]	W
Hod Hill	-	([+])	-	-	-	?	-	-	-	-	-	-	[8]		
Hunsbury		(+)	+ ?	1					+			8	8	1	B? W
Madmarston	-	(+)	-	-	-	-	-	-	-	-	-	1	1	-	W
Maiden Castle	?	+	-	-	-	-	-	+	4	-	-	-	[1]	-	W
Meare Village East	-	(+)	-	-	-	-	-	+	5	-	-	2	3	3	B? W
Meare Village West	?	(+)	-	5	-	-	?	+	+	-	-	2	1	9	B? W

Table 5:9 (cont.)

Site	Iron-smithing			Non-ferrous metalworking								Iron tools			Implements
	hearth, lining, or tuyère	slag	bloom, blank or waste*	ingot mould	ingot, billet, or part-made	wrought scrap*	hearth, lining, or tuyère	waste metal, or slag/dross	crucible or sherds	lost-wax mould fragment	'coin pellet' mould	tongs, or poker	forming	finishing or decorating	B: bone W: whetstone T: touchstone
Midsummer Hill	+	+	-	-	-	-	-	-	-	-	-	-	2	2	W
Mynydd Bychan	-	(+)	-	1	-	-	-	-	-	-	-	-	-	1	-
Oare		(+)											1		
Rainsborough Camp	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Sheepen	-	([+])	-	-	-	-	?	+	+	-	+°	3	1	-	-
Skeleton Green	-	-	-	-	-	-	-	1	-	-	+°	-	1	-	W
South Cadbury						+	?	+	+	+			2	1	W
Southcote	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Sutton Walls	-	(+)	-	-	-	-	-	-	1	-	-	[1]	-	-	-
Tre'r Ceiri	-	-	-	-	-	-	-	-	-	-	-	1	-	-	W
Twyn-y-Gaer	-	(+)	-	-	-	-	-	-	+	-	-	1	1	1	
Wakerley	+	+	-	-	-	-	-	-	-	-	-	-	1	-	W
Weelsby Avenue	?	+	+	1	+	-	+	+	c.1000	c.3000	-	-	1	7	B W
Wetwang Slack	-	[+]	-	-	-	-	?	-	+	+	-	-	-	[4]	B?
Witham Bury												3			
Woodeaton	-	-	-	1	-	-	-	+	1	-	-	-	-	2	-
Worthy Down, Headb'W	+	(+)	-	-	-	-	-	-	-	-	-	-	1	2	W
Worthy Down, Wonston													1		

* Off-cuts, part-formed, or for re-use

[] May not be Iron Age

° Metal residues detected in pellet mould

? Uncertain attribution

() Not analysed but probably smithing slag

Entries are not filled in where excavations have not been fully published, or controlled excavations have not taken place, or information is not available.

Sources: Tools: Appendix A. Debris: publication reports (Appendix C); Bayley 1984b; Linton and Bayley 1982a; 1982b; McDonnell 1986b; Northover 1988; Wilthew 1986; J. Dent (pers. comm.); A. Fitzpatrick (pers. comm.); J. Sills (pers. comm.)

Table 5:10 Occurrence of metalworking debris at Iron Age occupation sites from which no ferrous metalworking tools have been recognised

Site	Iron-smithing			Non-ferrous metalworking								Source
	hearth, lining, or tuyère	slag	bloom, blank or waste*	ingot mould	ingot, billet, or part-made	wrought scrap*	hearth, lining, or tuyère	waste metal, or slag/dross	crucible or sherds	lost-wax mould fragment	'coin pellet' mould	
Aldwick, Barley, Herts	1	(+)	-	-	-	-	-	-	-	-	-	Cra'ster 1961, 33
All Cannings Cross, Wilts	?	(+)	-	-	-	-	?	+	+	-	-	Cunnington 1923, 33, 53-4
Ashville, Abingdon, Oxon	-	+	-	-	-	-	-	-	3	-	-	Cleere in Parrington 1978, 89-90.
-												
Baldock, Herts	-	-	-	-	+	-	-	-	-	-	-	Stead and Rigby 1986, 122-3
Beeston, Cheshire	?	+					?		1			McDonnell 1987b
Boxgrove, W. Sussex											[+]	Bedwin 1983, 87
Breedon on the Hill, Leics	-	-	-	-	-	-	-	-	1	-	-	Kenyon 1950, fig. 6.6
Bryn-y-Castell, Gwynedd	+	+										Crew 1987; 1988b
Budbury, Wilts	-	-	-	-	-	-	-	+	-	-	-	Wainwright 1970, 140
Burgh, Suffolk	+	+	-	-	-	-	-	+	3	1	-	Tylecote in Martin 1988, 25
Camelford, Cornwall				1?								Thurnham 1956-9
Camerton, Glos	-	-	-	-	-	-	-	+	+	-	-	Wedlake 1958, 39
Castell Henllys, Dyfed		+							+			Cranstone 1988, 4
Castle Ditches, Llancarfan, Glam	?	(+)	-	-	-	-	-	+	1	-	-	Hogg 1976, 31-2
Catcote, Hartlepool, Tyne & Wear	?	-	-	-	-	-	-	-	-	-	-	Long 1988, 20-21
Chun Castle, Cornwall	?	(+)	-	1	-	-	-	+	-	-	-	Leeds 1927, 217-8, 223
Chysauster, Cornwall	-	(+)	-	-	-	-	-	-	-	-	-	Hencken 1933, 270
City Farm, Oxon		(+)										Chase <u>et al.</u> 1964-5, 95
Collfryn, Powys	-	-	-	1	-	-	-	+	+	+ ?	-	Britnell 1989, 114, 126-32
Copse Farm, W. Sussex	-	+	-	-	-	-	-	-	-	-	-	Brown, in Bedwin & Holgate 1985, 229.
Cow Down, Wilts	-	+	-	-	-	-	-	-	-	-	-	Tylecote 1983
Crawcellt, Gwynedd	+	+										Crew 1988a; 1989
Crickley Hill, Glos									1			Tylecote 1986, 234, table D
Dinorben, Clwyd	-	+	1	-	1	-	-	-	-	-	-	Gardner & Savory 1964, 226-7

Table 5:10 (cont.)

Site	Iron-smithing			Non-ferrous metalworking								Source
	hearth, lining, or tuyère	slag	bloom, blank or waste*	ingot mould	ingot, billet, or part-made	wrought scrap*	hearth, lining, or tuyère	waste metal, or slag/dross	crucible or sherds	lost-wax mould fragment	'coin pellet' mould	Source
Ditches hillfort, N. Cerney, Glos	-	[+]	-	-	-	-	-	[+]	[+]	-	+*	Trow 1988, 53, 55, Mf 1:A6
Earls Barton, Northants								+				Knight 1984, 165
Eaton Socon, Cambs								+				Knight 1984, 165
Fengate, Cambs	?	(+)	-	-	-	-	?	+	1	-	-	Hawkes and Fell 1943, 192;
-												Craddock in Pryor 1984, 174
Fifield Bavant Down, Wilts	?	(+)	-	-	-	-	-	-	-	-	-	Clay 1924, 461
Foxholes Farm, Herts	-	-	-	-	-	-	-	-	+	-	-	Tylecote in Partridge 1989,
-												214
Furzey Island, Poole Hbr., Dorset	?	+	-	-	-	-	-	-	-	-	-	Clough in Cox 1988, 65
Furzton, Bucks		+										McDonnell 1989
Harding's Down, Gower, Glam	-	(+)	-	-	-	-	-	-	-	-	-	Hogg 1973, 60, 67
Hengistbury Head, Dorset	+	+	-	-	1	+	+	+	11	-	-	Gowland 1915; Northover
-												1987; Salter 1987a; 1987b
Ilchester, Somerset	-	-	-	1	-	-	-	-	-	-	-	Foster in Leach 1982, 225
Ingram Hill, Northumberland	-	(+)	-	-	-	-	-	-	-	-	-	Jobey 1971, 89
Kingsdown Camp, Somerset	-	(+)	-	-	-	-	-	+	-	+	-	Gray 1930, 72, 86, 90
Kestor, Devon	?	-	-	-	-	-	-	-	-	-	-	Fox 1954, 38-40
Little Somborne, Hants	-	+	-	-	-	-	-	-	-	-	-	Bayley 1977; Neal 1979, 106
Little Waltham, Essex	-	-	2	-	-	-	-	-	-	-	-	Tylecote in Drury 1978, 115
Little Woodbury, Wilts	-	(+)	-	-	-	-	-	-	-	-	-	Bersu 1940, 53
Llanmelin, Gwent	-	(+)	1	-	-	-	-	-	1	-	-	Nash-Williams 1933, 262-3
Llanymynech, Powys	-	-	-	-	-	-	+	+	-	-	-	Musson and Northover 1989
Llyn Bryn Dinas, Powys	+	+					+	+	+			Thorburn 1988, 150
Long Wittenham, Berks	-	-	-	-	-	-	-	-	1	-	-	Savory 1937, 3-4
Merthyr Mawr Warren, Glamorgan	-	(+)	-	-	-	+	-	+	+	-	-	Fox 1927, 47-9
Mucking, Essex		(+)		1	?				+	?	-	Jones 1980; J. Bayley
-												(pers comm.)

Table 5:10 (cont.)

Site	Iron-smithing			Non-ferrous metalworking								Source
	hearth, lining, or tuyère	slag	bloom, blank or waste*	ingot mould	ingot, billet, or part-made	wrought scrap*	hearth, lining, or tuyère	waste metal, or slag/dross	crucible or sherds	lost-wax mould fragment	'coin pellet' mould	
Murton, Northumberland	-	+	-	1	-	-	-	-	-	-	-	Jobey and Jobey 1987, 185-7
Needham, Norfolk	-	-	-	-	-	-	-	-	-	-	+	Freere 1941, 51
Norbury, Glos		+										Bayley 1983a
North Cave, N. Humberside	-	+	-									McDonnell 1988c
Old Oswestry, Salop							?		+			Savory 1976, 76
Old Sleaford, Lincs		+									+■°	Jones et al. 1975, 238-41;
-												Heyworth 1987; Heyworth &
-												Wilthew 1987
Pill Rath, Dyfed	-	-	-	-	-	-	-	-	2	-	-	Williams 1948
Potterne, Wilts		[+]				+		+	+		-	McDonnell 1987c; Bayley 1987
Poundbury, Dorset	-	-	-	-	-	-	-	-	2	-	-	Bayley in Sparey Green 1987,
-												99
Rampton, Notts	?	+					?		2			Bayley 1983b
Rochester, Kent											+	Wilthew 1985
Roxby, N. Yorkshire	+	+	-	-	-	-	-	-	-	-	-	Inman et al. 1985, 198-9
Ructstalls Hill, Hants	?	+	-	-	-	-	-	+	-	-	-	Oliver & Applin 1978, 79-81
Runton Holme, Norfolk									+?			Clarke 1939, 93
Salmonsbury, Glos	-	-	-	-	-	-	-	+	1	-	-	Dunning 1976, 111
St. Mawgan in Pyder, Cornwall	-	-	-	-	1	+	-	+	+	-	-	Threipland 1956, 42-3
Scotton, Lincs											+	Tournaire et al. 1982, 433
Silchester, Hants	-	-	-	-	-	-	-	-	-	-	+*	Boon 1954, 68-70; P. North-
-												over (pers. comm.)
Slonk Hill, Sussex	-	-	-	-	-	-	-	+	2	-	-	Tylecote in Hartridge 1978, 97
Stanwick, N. Yorkshire							?			1		Spratling 1981
Swallowcliffe Down, Wilts	-	(+)	-	-	-	-	-	+	-	-	-	Clay 1925, 61

Table 5:10(cont.)

Site	Iron-smithing			Non-ferrous metalworking								Source
	hearth, lining, or tuyère	slag	bloom, blank or waste*	ingot mould	ingot, billet, or part-made	wrought scrap*	hearth, lining, or tuyère	waste metal, or slag/dross	crucible or sherds	lost-wax mould fragment	'coin pellet' mould	Source
Thorpe Thewles, Cleveland	?	+	-	1	-	-	?	+	11	-	-	McDonnell, Heslop, & Swain,
-												in Heslop 1987, 66, 89-92
Trevelgue Head, Cornwall	-	+	-	-	-	-	-	-	-	-	-	Bayley 1984c
Uley Bury, Glos	+	+	-	-	-	-	-	-	2	-	-	Saville 1983, Mf A10-B3
Verulamium, Herts	-	-	-	-	-	-	-	-	-	-	+■	Frere 1983, 30-2
Viables Farm, Hants	-	-	-	-	-	-	-	-	1	-	-	Millet & Russel 1984, fig.8.4
Waldringfield, Suffolk										+		Martin 1988, 25
Waysland Rath, Glamorgan	-	-	-	-	-	-	-	+	+	-	-	Wainwright 1971, 90-1
Weekley, Northants								+	1			Knight 1984, 165
Winchester City, Hants								+	1		[+]	Biddle 1966, 320;
-												Bayley 1983c
Winklebury Camp, Hants	?	+	-	-	1	-	?	-	1	-	-	Bayley in Smith 1977, 80-3
Winnall Down, Hampshire	?	+	?	-	-	-	?	-	1	1	-	Bayley, & Tylecote, in
-												Fasham 1985, 92-3
Winterborne Monkton Down, Wilts	-	-	-	-	-	-	-	-	1	-	-	Anon. 1913, 109
Wittenham Clumps, Berks	-	-	-	-	-	-	-	?	1	-	-	Hingley 1980, 48
Wolsty Hall, Cumbria	-	-	-	1	-	-	-	-	-	-	-	Jobey 1973, 41-2
Wookey Hole, Somerset	-	(+)	-	-	-	-	-	-	-	-	-	Balch 1911, 577
Worm's Head, Glamorgan				1								Savory 1974

* Off-cuts, part-formed, or for re-use

() Not analysed but probably smithing slag

■ With single pellet <u>in situ</u>

? Uncertain attribution

[] May not be Iron Age

• Metal residues detected in pellet mould

Entries are not filled in where excavations have not been fully published, or controlled excavations have not taken place, or information is not available occupation) where tools have not been recognised in order to present an overview, in conjunction with Table 5:9, of the range of evidence for metalworking during the Iron Age.

It is not envisaged that Table 5:10 forms a complete list either for the number of sites which have yielded metalworking evidence, nor for the entries under individual sites particularly where analysis of finds is still in progress. Given the reservations in attribution of residues expressed above, excluded from Table 5:10 are sites where a few pieces of 'iron slag' have been noted unless there are reasons to believe that the material was likely to be from iron-smithing and from a definite Iron Age context. Also excluded are some sites where 'scrap' metal has been noted or where the description of residues suggests the possibility of fuel ash slag.

The apparent absence of tools from the sites listed in Table 5:10 may reflect difficulties in recognising metalworking tools, particularly incomplete or fragmented examples.

Many of the assemblages of ironwork which were examined by the writer certainly contained artifacts which could conceivably have been fragments of tools, but without sufficient diagnostic attributes to be certain of their identity. Possible fragmentary tools are noted in Section 5.2 (Gussage All Saints, Beckford, Fison Way), and tools of uncertain identity in Chapter 3 (see especially Tables 3:4, 3:9 and 3:10). Other excavated sites such as Bagendon, The Breiddin, Casterley Camp, Croft Ambrey, and Ham Hill - all with sizable assemblages of ironwork - may may also have significant additional tools, and the assemblages discovered at sites such as Bigbury and Hunsbury may be far from complete. However, from these ten sites metalworking tools <u>have</u> been identified and therefore they appear in Table 5:9 and Appendix C.

The total number of ferrous metalworking tools known is likely to be a small fraction of the total deposited and excavated or discovered, not only because of recognition problems and the nature of the archaeological record (both factors apply to other categories of artifacts), but also due to corrosion in the ground and after excavation (cf. Figure 2:1).

5.3.5. Frequency of different metalworking processes

Figure 5:10 shows the frequency of metalworking at sites from which Iron Age metalworking debris has been determined. In Figure 5:10a, the relative proportions of the four main (metal) manufacturing processes are indicated in a sample of twenty-four sites which also yielded metalworking tools. Excluded are metalworking activities for which a pre-Roman date is uncertain or where mid-first century AD horizon activity is indicated, residue types which are non-diagnostic of a specific process, intermediate products, and unused 'coin pellet moulds'. Of the sample, the evidence suggests the following:

1) 14 sites have evidence for a single metalworking process, 6 sites for two processes, and 4 sites for three processes
2) Iron-smithing at 17 sites, 12 of which also have non-ferrous working
3) 5 sites with both non-ferrous wrought working and founding, another 5 sites with only wrought working, and 3 sites founding. At a further 3 sites the non-ferrous process(es) cannot be determined
4) Used 'coin pellet moulds' occur at 4 sites, 3 of which (Bagendon, Sheepen, Skeleton Green) have no certain evidence of other working.

Figure 5:10 b-d show the frequency of ironworking to non-ferrous metalworking. Excluded are the same types of materials not incorporated in Fig. 5:10a with the exception that Fig. 5:10d also includes certain or possible smelting residues in order to examine a greater number of sites, and also to compensate for those residues which cannot, or have not been characterised (i.e. 'ironworking' slags). Except for possible coin production (or other specialised artifacts processed in slab moulds), the non-ferrous residues are primarily from the working of copper alloys. According to the data available, the diagrams suggest that the working of iron and non-ferrous metals occurred on a roughly equal basis, though not necessarily during the same period of Iron Age occupation of the sites, and that both metal types were worked at a high proportion of sites. There are slight indications that non-ferrous metals were worked at a greater number of sites, though there may be a bias due to interim publications or specialised reports concentrating on certain types of finds - those 'attracted' to the archaeological record (cf. Haselgrove 1987, 34). In addition, non-ferrous metalworking produces a greater variety of residues, and ones which are more likely to have been

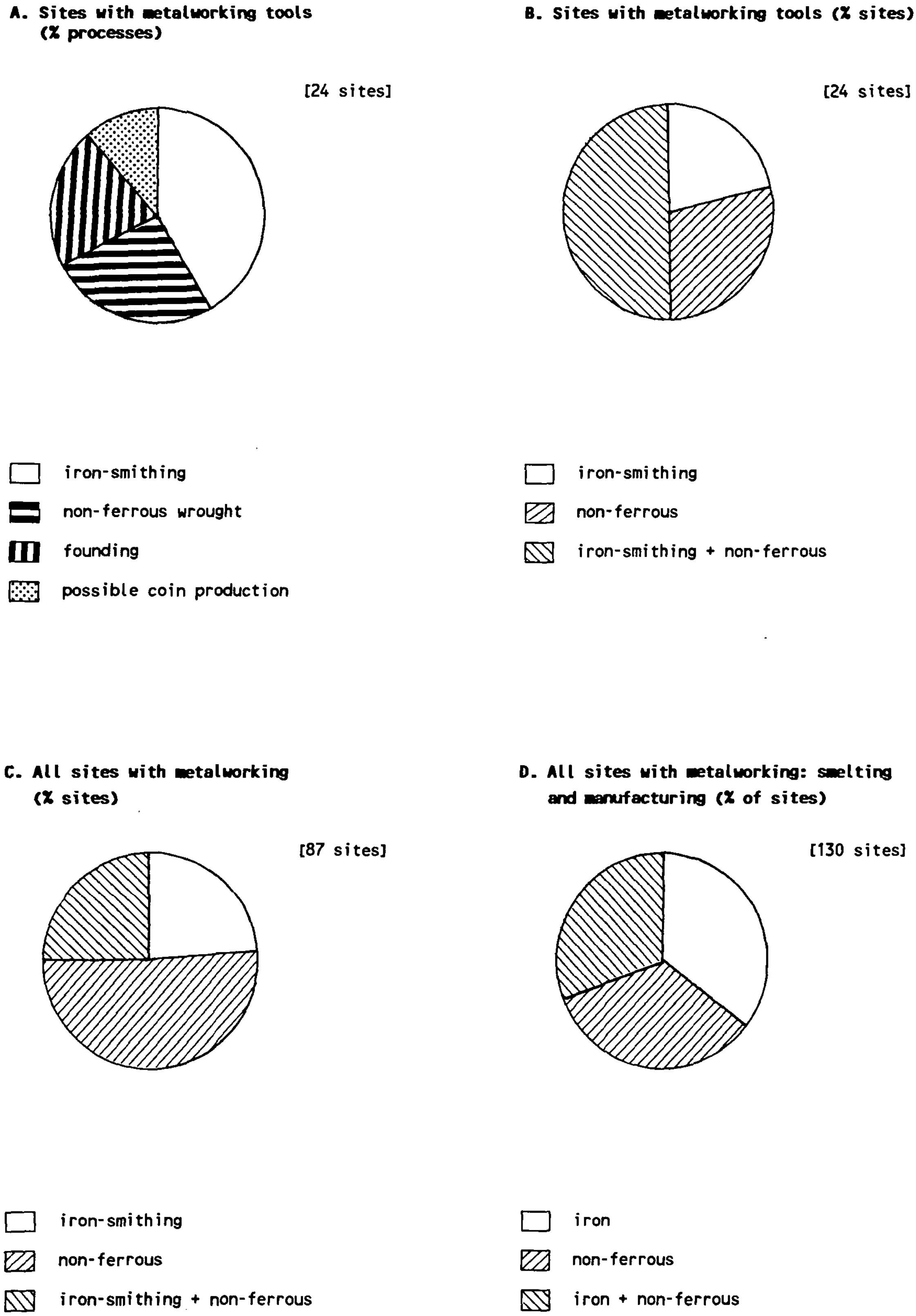


Figure 5:10 Frequency of metalworking at Iron Age occupation sites (%)

(Sources: as for Tables 5:9 and 5:10, with additions from Tylecote 1986, table 72) recorded and retained from less recent excavations.

With only a few exceptions, the nature of the evidence does not at present enable more thorough analysis in terms of chronological extent and the relative size of the industries, and whether these activities were concurrent.

5.4. Groups with metalworking tools from occupation sites

Metalworking tools occur in the following groups of metalwork from occupation sites: Garton Slack, Madmarston, Bulbury, Hod Hill, Barbury Castle, and Bigbury. The circumstances of discovery have not always assisted interpretation; the likely attribution and dating of the groups is discussed below.

(a) Garton Slack, North Humberside

Below a grain silo (Grain Pit 1) at Garton Slack (Brewster 1975; 1980) was a shallow rectangular pit which contained two pokers (Nos 1 and 5) and a pair of tongs (No. 38). It seems that the tools had been deliberately placed in the pit and covered, possibly with straw and compressed soil, in order to conceal them beneath the silo (Brewster 1980, 363-4). In the fill of the silo was a large quantity of charred grain, together with pieces of charcoal from oak timbers which may once have formed the lining or roofing of the silo. The excavator suggests that the grain may have caught fire by spontaneous combustion, destroying the silo, which was probably abandoned and filled in. The tools were then lost or forgotten (Brewster 1980, 364).

A radiocarbon date of 180 ± 70 years b.c. [Har-1228] was obtained from the timbers. This is a *terminus post quem* for the felling of the tree. The timbers may have been re-used and therefore a date later in the range seems more probable for the deposition of the tools.

No metalworking debris was recorded from Garton Slack, which may question the role of these smithing tools at the settlement, and in consideration of their unusual burial, suggests a possible ritual element in their deposition.

(b) Madmarston, Oxfordshire

At Madmarston hillfort, a group of ironwork comprising a poker (No. 8), twelve currency bars, a shaft-hole axehead, a sickle and two bridle-bits, was found undisturbed beneath the stone floor of the tail of the inner rampart (Fowler 1960, 41-3, fig. 18, nos 1-6). Stratigraphy suggests a late second century BC date for deposition of the group (Fowler 1960), supported by the generally accepted date of currency bars (Allen 1967; Trow 1988). The group seems to have been deliberately concealed; ritual deposition may be indicated by the currency bars (cf. R. Hingley forthcoming).

A small quantity of ferrous slag and scraps of lead recovered elsewhere from Madmarston attest metalworking at the site (Fowler 1960, 20, 30, 45).

(c) Bulbury, Dorset

The group of metalwork and glass beads discovered near the centre of Bulbury hillfort has been discussed by Cunliffe (1972). On balance, he suggests that the material was unlikely to be from a single deposit, but that the firedog, copper alloy artifacts and glass beads may represent the grave goods of a male burial and a female burial respectively, while the remainder of the ironwork derived from a blacksmith's hoard. These latter items comprise two set hammers (Nos 56 and 57), a shaft-hole axehead, a bar, and an anchor and chain. On the basis of the condition of the items, Cunliffe suggests that they were a hoard of waste metal collected together for reforming (Cunliffe 1972, 306). However, inspection of the artifacts suggests that, like the anchor, they had been chemically stripped (Alcock in Cunliffe 1972, 307). Such treatment could account for the incompleteness of one of the hammers (No. 57) and for the 'slag crevices' observed by Cunliffe (1972). It thus seems unlikely that these iron artifacts were scrap, although it is possible that they represent both a single deposit, and a group which once belonged to a metalworker.

In the event that the items were associated, the anchor could date the deposition of the group from the first century BC to the Roman period (Cunliffe 1972, 302). At present, shaft-hole axeheads give little assistance for dating. The non-lugged, simple pre-Roman type occurs and in a hoard at Hod Hill (C. Saunders forthcoming), Madmarston (Fowler 1960, 42-3, no. 14, fig. 18, 5) and South Cadbury (Alcock 1969, 36, pl. XX) - all with associated currency bars and the latter also with clay slingstones. Another was discovered in a possible hoard at Bigbury (Boyd Dawkins 1902, 214, pl. I, 2, b) with first century BC ironwork (Section 5.4.f). Three were found at Fiskerton

(Section 5.5.b), and one from Hunsbury is unstratified (Fell 1936, 65). A later Iron Age date is favoured for the majority of these axeheads (but excluding those from Fiskerton) based on their association with currency bars and other artifacts. It is possible, therefore, that the two hammers (Nos 56 and 57) date from the later Iron Age, but as Cunliffe (1972, 306) has pointed out, the group may have been unrelated items.

Controlled excavations have not been carried out at Bulbury (Cunliffe 1972); thus there is little evidence of the duration of occupation at the hillfort, nor of any metalworking activity.

(d) Hod Hill, Dorset

A group of six iron artifacts from Hod Hill, 'said to have been found at Hod Hill during World War II' (British Museum accession record P1975 7-1), comprises a hammer (No. 59), a currency bar, a shaft-hole axehead, a knife with a sinusoidal handle, a hooked block, and a bill-hook (C. Saunders forthcoming). If the items were associated, which is by no means certain, the presence of the currency bar may suggest a mid to late Iron Age date (Allen 1967) for the group. A later Iron Age date is favoured for the majority of known shaft-hole axeheads of Iron Age type (Section 5.4.c). The knife is very similar to one from the group of ironwork from Barbury Castle (Section 5.4.e), for which a mid-Iron Age date seems possible. The hooked block is not unlike the one discovered also at Barbury Castle (No. 47), which seems to have been used there as an anvil (Chapter 3.4). A similar block was found in a fifth to third centuries BC context at Gussage All Saints (Wainwright 1979, 104, no. 1019, fig. 80), and others, of later date, are indicated in Table 3:1.

The circumstances of discovery and possible dating of other material from Hod Hill has been discussed by Manning (1985, 182-3). Seven tools have been catalogued in the current study from the Durden and Bean collections, but only the two hammers (Nos 81 and 83) are typologically Iron Age. The others cannot be dated by form, and there is a possibility that they may have come from the adjacent Claudian fort which was destroyed by fire in AD 51 (Richmond 1968, 119-21).

(e) Barbury Castle, Wiltshire

A group of iron artifacts from Barbury Castle was discovered in unknown circumstances (MacGregor and Simpson 1963). The group comprises a hammerhead, an anvil, seven 'awls', six sickles, three spearheads, a ferrule, five rings, a nave-band, a knife and a possible linch-pin fragment. MacGregor and Simpson (1963) suggest that the group may have been a blacksmith's hoard, based on the presence of the hammerhead and the 'earth anvil', and they further suggest that the group dates to about 200 BC - 50 BC (Hawkes' First or Second Southern B).

The hammerhead (No. 75), now lost, was apparently compared by Grinsell with hammers from Bredon Hill, for an entry in the museum accession book records 'a neat hammerhead (cf. Bredon Fig. 6)'. The anvil (No. 47), much burred by use, is of the hooked block type discussed in Chapters 3.4 and 5.4.d. Recent conservation of the items from Barbury Castle suggests that five of the 'awls' are possibly metalworking tools (Nos 208, 209, 210, 213, 227), another may be a tanged ?punch (MacGregor and Simpson 1963, fig. 2.18), and seventh is too fragmentary to identify (Table 3:10).

One of the iron rings (MacGregor and Simpson 1963, 394, no. 15, fig. 2) appears to be very crudely twist-decorated and is probably not a finished artifact. Another ring shows no sign of the zoomorphic head described by MacGregor and Simpson (1963, 394, no. 16, fig. 2). It seems possible that the five rings may have been scrap items, perhaps bracelets rather than terrets. The other items in the hoard are not as readily datable as MacGregor and Simpson (1963, 396-8) suggest. The types of agricultural blades found at Barbury Castle occur commonly throughout the later Iron Age (cf. Rees 1979), and the knife with sinusoidal handle is closely paralleled with one from Hod Hill (Section 5.4.d).

Clearly the group from Barbury Castle need not have been a single deposit, although the anvil, hammerhead, small tools, the rings, and possibly other items, may once have been a group of metalworker's tools and scrap. Controlled excavations have not been carried out at Barbury Castle but the few sherds of pottery which have been found are of early and middle Iron Age date (MacGregor and Simpson 1963).

(f) Bigbury, Kent

Between 1861 and 1895, at least six groups of ironwork, together with a small quantity of pottery, were discovered during gravel quarrying at the south side of Bigbury hillfort (Boyd-Dawkins 1902; Jessop 1932, fig. 2). Since some of the discoveries comprise only ironwork, including sizable items such as a fire-dog and slave chains, it is very possible that they constitute one or more hoards (Manning 1972, 230). It has been suggested that the hearth furniture may have accompanied burials (Jessop 1932; Hogg 1975, 133), though Thompson (1983, 252) considers that the groups can be attributed to domestic use - items which were abandoned during or soon after Caesar's attack in 54 BC.

There are four metalworking tools from these groups. The two hammers (Nos 63 and 68) were discovered in 1895 together with spear-heads, a dagger, agricultural implements and a shaft-hole axehead (Jessop 1932, 97-8). Chisel No. 95 may also be from this group, whereas chisel No. 93 is from a group discovered around 1887.

Occupation at Bigbury extended from the fifth-third centuries BC to the middle or late first century BC (Thompson 1983). If the metal-working tools and the other ironwork are connected, then a date around the middle or late first century BC seems possible for their deposition on the basis of the slave-irons (Manning and Saunders 1972), supported by probable late dating of the cauldron chains (cf. Manning 1983). However, associations between the metalworking tools and the datable items are dubious, but nevertheless, the two hammers and possibly chisel No. 95 may be from a hoard.

During excavations in 1978-80, an anvil (No. 46) was found set into natural clay, and it has been suggested that this may have formed the site of a temporary smithy (Thompson 1983, 251-2). No metalworking debris has been reported from Bigbury.

5.5. Groups with metalworking tools found away from occupation sites

Four groups of metalwork with no apparent connections with occupation sites have yielded metalworking tools: Waltham Abbey, Fiskerton, Llyn Cerrig Bach, and Santon (Norfolk).

(a) Waltham Abbey (Town Mead), Essex

The Waltham Abbey hoard was discovered in 1967 by workmen digging gravel from below the peat and clay overburden on the town meadow (Manning 1980; 1985, 184). The tools were found in their machinery, but are said to have lain together except for a hammer which was found nearby. Timber fragments noted at the time of discovery suggest that the hoard may have been contained in a box.

The hoard comprises thirteen metalworking tools (discussed below), a sword, a loop-headed linch pin, a billhook, an iron bar or cart tire (Manning 1980), a lead lump, a whetstone, and six woodworking tools - an adze, scraper, two gouges and two (Manning 1985, B11, B24, B45, B50, B75, B76). Typologically the sword dates from the first century BC, and the linch-pin to the late first century BC or early first century AD (Manning 1980, 87-9; 1985, 184). The hoard is therefore likely to have been deposited during or after the latter part of the first century BC, and a first century AD date is not improbable.

The metalworking tools comprise three pokers (Nos 9, 29, 30), five tongs (Nos 33-37), two swage anvils (Nos 49 and 50), a swage-hammer (No. 58) and a file (No. 141). The pokers and tongs had been deliberately bent before deposition, which, together with their burial below the peat and clay (and probably below the Iron Age water level of the river), suggests that the hoard was ritually deposited. Despite careful attempts to recover all the items, some tools are incomplete though it seems probable that they would have been deposited whole - even if bent and broken. As Manning (1985, 4) has noted, the swage grooves on the hammer match one of each pair on the anvils, and there must have been another swage-hammer in the original tool-set to correspond with the second groove on each anvil. It is possible therefore that the hoard is not complete, and that some tools (such as the hammer found nearby) were deposited separately or were redeposited by water movement.

The metalworking tools seem likely to be iron-smithing tools principally because of the paired swages, and also because of the size of the tongs and the swage hammer, and the presence of iron hammer-scale and haematite on anvil No. 45.

No evidence of Iron Age or Roman settlement has been located in the vicinity of the findspot (cf. Drury 1980, fig. 18; Drury and Rodwell 1980, figs 21 and 24).

(b) Fiskerton, Lincolnshire

During 1979 a stretch of the River Witham was dredged, exposing the tops of a number of timber posts running perpendicular to the river. In 1981 the area was excavated in order to investigate the function and date of the posts and to establish a context for some of the metalwork which had been found in the vicinity, both during previous dredging operations (White 1979) and more recently through metal detecting (Field 1986).

The timbers were found to be part of a double row of clustered posts which had formed a causeway leading over soft peaty ground to the riverside (Field 1986, fig. 15). A 20m length of the causeway was excavated in 1981; a further 60m length was partly exposed during ploughing of the adjacent field, and this was recorded and sampled for dating. Dendrochronology has shown that the causeway was actively repaired in the years 457/6 to 339 BC (Hillam 1985; Field 1986, and pers. comm.). It is possible that the causeway was constructed prior to 457 BC and that it continued in use for some time after the final repairs. Initial radiocarbon dating from the timbers has provided dates of 510 ± 70 bc [Har-4472] and 330 ± 70 bc [Har-4471] (Field 1986). Environmental evidence confirms that wet but not waterlogged conditions prevailed throughout the use of the causeway.

The excavation yielded pottery dating from the fifth century BC into the Roman period, a group of ferrous Iron Age tools, Iron Age weapons, and Iron Age artifacts such as bone implements possibly for weaving. A few other artifacts which were found can be assigned to the Roman period, for example two Kentish ragstone whetstones, whereas a pruner and a grooved lump of marcasite (possibly a strike-a-light) may well be Iron Age (N. Field pers. comm.). Water movement had disturbed the stratigraphy and some of the finds near the causeway cannot be reliably dated from their context. Nevertheless, a flood silting clearly delineated post-Roman activity.

The tools which are relevant to this study were clustered in a 4m square area to the east of the causeway and a further three tools were found 4m away. They were embedded in layers of brushwood which had been pegged into soft ground at the river's edge and sealed beneath a silting from the river. A stratigraphic relationship between the brushwood and the causeway could not be established. Vertical stratigraphy has given little assistance in interpreting any relationship between the tools; the larger and heavier tools were from lower levels - presumably because they had sunk into the peat. The tools may have been a single deposit though there is a chance that they could have been deposited as separate groups or individually, and their deposition need not have been related to the use of the causeway (N. Field pers. comm.)

There are seventeen items in this group of tools. The ten metalworking tools comprise a fragment of a possible poker (No. 31), bench anvil (No. 54), top-swage (No. 55), two hammers (Nos 62 and 71), four files (Nos 128, 135, 142, 145), and a possible punch (No. 172). The six woodworking tools comprise three shaft-hole axeheads, two files (Table 3:5, f and g) and a slender gouge. There is also a pull-'saw', whose purpose may have been agricultural or ritual rather than for woodworking (I. Stead forthcoming).

The 'saw' and one of the woodworking files (a coarse-cut float) have decorated antler handles, and in addition, both are decorated on the iron. The 'saw' is engraved with straight and curved lines (Plate Ia), which, since these occur on both sides of the blade, suggest that it is not a re-used weapon blade. The float has traces of a circle on the edge of the blade close to the tang.

The decoration on the handle of the float dates to around the fourth century BC (Stead 1985b, 17-18, fig. 20, e). The axeheads offer little assistance for dating. As discussed in Section 5.4.c, the six of shaft-hole type found elsewhere in Britain are all from hoards which have been broadly dated by associated metalwork to the latter part of the Iron Age. Two of the Fiskerton axes are virtually identical and are larger than other known Iron Age examples from Britain; they are more closely paralleled with ones from La Tène (Vouga 1923, pl. XLIII, 6 and 7). Unfortunately the tools cannot be more closely dated at present, but if the metalworking tools and woodworking tools are from a single deposition, then a date around the fourth century BC is suggested by the handle of the float.

This provisional date for the tools correlates with the dates for the repair of the causeway and thus it seems possible that the deposition of tools may have been related to the use of the causeway. No evidence of an Iron Age settlement has been found in the immediate vicinity of the causeway, though it has been suggested (Field 1986) that occupation may have been to the north, under or near the modern village of Fiskerton. All the tools appear to have been used, but none heavily. The loss of so many tools in peaty surroundings (but not deep water) seems unlikely, and ritual deposition seems very probable.

Apart from the two large distinctive axeheads and the two decorated tools mentioned above, the group of tools is unusual in other ways. The two hammers (Plate IIa), which are interpreted as specialised hammers (V. Fell forthcoming), had been selectively hardened at their faces (above, p. 116-7), which implies considerable technological knowledge and skill in their manufacture. Two of the files (Nos 142 and 145; Plate IVa) have pronounced tang junctions - the only two with this feature of all the known files from the Iron Age (p. 134).

(c) <u>Llyn Cerrig Bach, Anglesey, Gwynedd</u>

The discoveries made during peat extraction during 1942-3 include a large quantity of metalwork, mostly weapons and chariot and harness fittings (Fox 1946). There are also animal bones, pottery, currency bars, and two pairs of tongs (Nos 39 and 43). The items which can be dated stylistically span approximately 200 years, and multiple ritual deposition during the period from the second century BC to the early first century AD has been suggested (Fox 1946; Savory 1976a, 49).

The presence of only two metalworking tools from the large series of depositions seems unusual, but of the 150 or so artifacts found, there was only one other certain tool or implement - a sickle.

(d) <u>Santon, Norfolk</u>

In 1897, a cauldron containing metalworking tools, copper alloy scrap metal, and other items was found in a garden at Santon, Norfolk (Smith 1909; Clark 1939, 70-2, 100). (The group is sometimes referred to as the Santon Downham, Suffolk hoard.)

The group contains items which are stylistically late Iron Age, together with some early Roman material such as Claudio-Neronian brooches. A date *c.* 60 AD has been suggested for the deposition of the hoard (Clarke 1939; Spratling 1975). The quantity of sheet metal scrap, off-cuts and tools suggests that it was a metalworker's hoard intended for recovery (Spratling 1966b; 1972, 349). Sherds of Iron Age pottery found in the vicinity suggest that there may have been a settlement nearby (Clarke 1939, 100).

The tools include two copper alloy formers possibly for forming sheet metal bosses (Smith 1909, fig. 3; Spratling 1970a, 190, fig. 4), two pairs of tongs (Nos 41 and 42), a file (No. 136), a possible hammer (No. 85), and an iron disc (Smith 1909, pl. XVII.1, top right) which may conceivably have been a poker-head (above, p. 90). If the identifications are correct, the hammer and poker appear to be typologically Iron Age, but the tongs and file cannot be assigned a date from their forms. The group has never been fully published and unfortunately the ironwork has deteriorated in recent years which prevents adequate examination of the iron tools.

Spratling identifies a small bronze anvil from the group of metalwork (Spratling 1970a, fig. 4, top left), but this seems more likely to be an unfinished casting - possibly a vessel foot.

5.6. Burials

Metalworking tools have been found in five Iron Age burials from three culturally and geographically distinct cemeteries, and a further three tools are from possible graves from a fourth distinct burial zone.

(a) Rudston, North Humberside

The 'Makeshift' cemetery forms part of an extensive barrow cemetery between Rudston and Burton Fleming from which 207 inhumations have been excavated (Stead 1976, fig. 5; 1979, 11-15). The two burials which contained metalworking tools belong to a distinct group of fifty-four east/west graves, unmatched in orientation, position and grave goods in any other 'Arras culture' burials (I. Stead pers. comm.; Whimster 1981, 287-8). Both burials date to the first century BC (I. Stead pers. comm.).

Burial 154 was an extended, young, probable male accompanied by an iron sword, a pair of tongs with coupler (No. 40), a hammer (No. 78), two spearheads and a possible wooden shield (I. Stead forthcoming). The tongs and coupler had been placed across the sword to the right of the body and the hammer was close to the jaws of the tongs. Traces of mineralised textile on the tongs (Crowfoot 1989) and the coupler suggest that these (or the body) may have been wrapped.

Burial 87, an extended, young, probable male was furnished with a hammer (No. 82) and a tanged, long iron blade, possibly a tool (I. Stead forthcoming).

(b) King Harry Lane, Hertfordshire

The Iron Age cemetery at Verulamium yielded 455 cremations and 17 inhumations (Stead and Rigby 1989). Most of the cremations were inurned, but six were in boxes and others were apparently loose. The main use of the cemetery was between AD 1 and AD 60, with limited intermittent use extending into the second century AD.

Burial 456, an adult cremation, with a hammer (No. 79) and two iron nails in an imported Barbotine beaker, is assigned to Phase 2 (AD

30-55) of the cemetery (Stead and Rigby 1989, 390, fig. 178). (Nails, excluding hobnails and those from boxes and boards, occur as grave finds in forty-five other burials.)

Burial 295, an adult cremation, with a burnt nail (presumably from a fired wooden object), was placed with a hammer (No. 65) and a short iron tube inside a wooden 'box' (defined by iron fittings), and accompanied by a Samian platter dated to AD 50-65 (Stead and Rigby 1989, 110-1, 346, fig. 147). The burial is assigned to the final stage of the main use of the cemetery (Stead and Rigby 1989, 204-7), in Phase 4a (after AD 60). The angled form of the hammerhead is more typically Iron Age than Roman (above, p. 114), though the type is not closely paralleled with examples from Britain.

(c) Whitcombe, Dorset

At Whitcombe, a small burial ground of twelve inhumations lay adjacent to a later Iron Age and Romano-British settlement. Nine of the graves were recovered complete, and of these, eight were accompanied by typical Durotrigian grave-goods (Whimster 1981, 261-2). The other, Burial 12 (Aitken 1967, 127, fig. 6; Collis 1972, fig. 2), was a male adult about 27 years old, accompanied by a first century BC sword, scabbard fittings, a spearhead, a 'pseudo-La Tène II' bronze brooch dating possibly to the first century AD, an unidentified bronze item, a hammer (No. 67), a file (No. 131), and a chalk ring. The latter three items were closely positioned near to the right elbow. The chalk ring (42mm diameter with an 8mm central perforation) may have been the fly-wheel of a pump-drill (Stead 1985b, 9) and possibly therefore a metalworking tool. The burial probably dates from the first half of the first century AD, but was likely to have been before the Roman conquest (I. Stead pers. comm.).

(d) Witham Bury (Chipping Hill Camp), Essex

During 1844, 'discoveries of three skeletons, and weapons or instruments in iron' (Repton 1844) was reported during the construction of a railway through the hillfort. The skeletal material has not survived, but the three iron artifacts have been commented upon subsequently as possible grave finds (Spurrell 1887; Whimster 1981, 23, 230), and described and discussed as pokers by Rodwell (1976). It is possible, but by no means certain, that the pokers (Nos 2, 3, 4) were grave goods from one or more of three burials.

Inhumations have seldom been recorded in Essex, nor indeed within the Welwyn cremation zone of south-eastern England (Whimster 1981), and it may be significant that six cremations were also discovered in 1844 during ploughing of a nearby field (Repton 1844). If the pokers were grave goods, it seems plausible that they predate the Welwyn Culture period and thus date to before the mid-first century BC.

Limited excavations during 1969-71 across the defences of the hillfort yielded Middle Iron Age pottery (Rodwell 1976, 43). Thus, on the basis of the limited pottery from the hillfort and the vicinity, a mid-Iron Age date is generally preferred for the occupation, and for the pokers (Rodwell 1976; Whimster 1981), but there is nevertheless the chance that the pokers were not associated with the main occupation of the hillfort - nor with burials.

5.7. <u>Discussion</u>

5.7.1. Archaeological distribution of the metalworking tools

The principal categories of material evidence for the main manufacturing processes are compared in Table 5:11, indicating key sites or frequency of occurrence of finds, where of particular relevance.

Residues are the main indication of metalworking activity assuming that waste products were not brought to a site, whereas intermediate products such as blooms, ingots, billets, and currency bars may have been transported away from their site of origin for redistribution. Tools may be found at the site of their manufacture, alteration, use, storage, or at other locations. Similarly, accessories do not necessarily indicate metalworking activity; as Haselgrove has noted, even if the attribution of 'coin pellet moulds' is correct, their occurrence need not mean that blanks were produced at the same area or at the same site unless there are clear indications of use, nor that the blanks were then struck at the site (Haselgrove 1987, 29). Crucibles may have been produced at one site and transported to another for use, though the presence of metallic residues on crucibles does indicate metal melting - whether for ingot production, founding, coin or coin pellet production, or coating other metals. Only at Weelsby Avenue has a large deposit of crucibles been found, but interpretation awaits analysis of the group.

Table 5:11 Summary of evidence for the main metalworking processes (excluding smelting)

Process	Primary evidence	Secondary evidence	Comments
Iron smithing	Hearth with smithing slag Smithing slag in quantity Hammerscale	Forging tools Isolated smithing slag Bloom Billet Part-manufactured items Off-cuts	Distinct forging tools have seldom been found with associated debris (but note Casterley, Gussage All Saints, Hunsbury, Weelsby Avenue). Abundant slag and hammerscale at Gussage All Saints and Maiden Castle. Slag frequently found in secondary contexts. ?Bloom found at Danebury and Little Waltham; ?billet at Lesser Garth. Off-cuts at Gussage All Saints. Currency bars found in '2ndry contexts'.
Wrought non-ferrous metalworking	Billet Part-manufactured items (+ tool-marks) Off-cuts	Ingot; ingot mould Hearth with residue Forming tools Finishing tools Melted metal waste	Characteristic hammers have not been found with debris. Ingot found at 5 sites. Ingot mould found at ≥ 13 sites. Billet found at Gussage All Saints and Croft Ambrey (and another found in a hoard at Ringstead). Semi-finished products at Baldock, Gussage All Saints, Weelsby Avenue.
Casting	Investment mould Failed casting Part-manufactured Ingate etc	Crucible Melted metal waste Hearth with residue Wax-forming implements Finishing tools	Moulds at ≥ 14 sites (note Gussage All Saints & Weelsby Avenue). Products identified at Beckford, Gussage All Saints, Weelsby Avenue, Wetwang Slack. Failed castings at Gussage All Saints and Weelsby Avenue. Ingate/sprue-cup at Gussage All Saints, Hengistbury Head, and Glastonbury. Bone wax-forming implements at Gussage All Saints, Weelsby Avenue, Wetwang Slack, and possibly Glastonbury and Meare. Finishing tools(?) found in debris at Gussage All Saints & Weelsby Avenue.
Coin making	'Coin pellet mould' with pellet or residue <u>in situ</u>	Dies and stocks Crucible Melted metal waste Hearth with residue Unused 'pellet mould'	'Pellet moulds' from early-mid C1st AD contexts at ≥ 13 sites. Single pellet <u>in situ</u> at Verulamium (copper alloy) & Old Sleaford (silver alloy). Metallic residue detected in moulds at Bagendon, Ditches, Fison Way, Gatesbury (Puckeridge), Old Sleaford, Sheepen, St. Albans, Silchester. No certain dies have been identified in Britain (alleged dies at Bagendon (Clifford 1961, pl. XLVI) are unlikely candidates).
Composite technology	Part-manufactured	Mould; tools Crucible Waste metal	Scrap bronze-coated iron bridle-bit link at Gussage All Saints. Mould fragments, possibly for casting bronze terminals on to iron, at Gussage All Saints and Weelsby Avenue.

Tools rarely assist in determining the metalworking process and conversely, metalworking associations seldom assists in attribution of tools to a particular process. Some of the reasons are:

(1) Iron-smithing

Tools characteristic of iron-smithing are long-handled chisels and punches, and large hammers. The abundance of smithing tools at Hunsbury suggests that there was considerable iron-smithing, but the circumstances of discovery has not enabled any relationships to be established with the 'considerable quantity of iron slag' (Fell 1936, 67).

Probable and possible associations of iron-smithing tools with ferrous residues occur only for hammer No. 64, hot chisel No. 105, hot punches Nos 164, 166, and 167, and less certainly for hot chisels No. 92 and 99. Only No. 64 was associated solely with iron-working slag.

(2) Wrought non-ferrous working

Wrought non-ferrous metalworking is likely to leave the least amount of waste material, but this activity may be inferred from the presence of billets and part-manufactured items. For reasons discussed in Chapter 3, iron also was cold worked during the Iron Age, possibly sometimes during forming, but certainly it was decorated by cold techniques.

The tools which seem most characteristic of cold forming techniques are specialised hammers such as those suggested in Chapter 3.6 to be for raising and sinking. The most likely examples of these have been found unstratified at Hunsbury (Nos 61 and 72) and Ham Hill (Nos 66 and 76), in unstratified occupation layers Bredon Hill (No. 73 and ?No. 74), and in a hoard of tools at Fiskerton (Nos 62 and 71).

(3) Casting

Casting involves very little if any working of metals and hence the employment of a narrow range of iron tools, though it seems likely that many castings may have required finishing - with chisels, files or abrasives to remove sprues, casting flaws and imperfections. Some castings may have been worked with fine tools to refine or complete any decoration (cf. Spratling 1972, no. 150).

The number of files and fine tools recovered from metalworking deposits at Gussage All Saints and Weelsby Avenue may suggest that castings were commonly finished with iron tools, though of course the deposits at both sites include residues from wrought working (iron and bronze) and therefore the usage of the tools cannot certainly be associated with the *cire-perdue* casting.

(4) Coin production

There is no direct evidence for the manufacture of coins in Britain (Haselgrove 1987). Thirteen sites at least have yielded moulds possibly for the production of coin pellets, which at eight sites contained metal residues or pellets, but dies and stocks have not been found, nor have moulds for the production of cast coins.

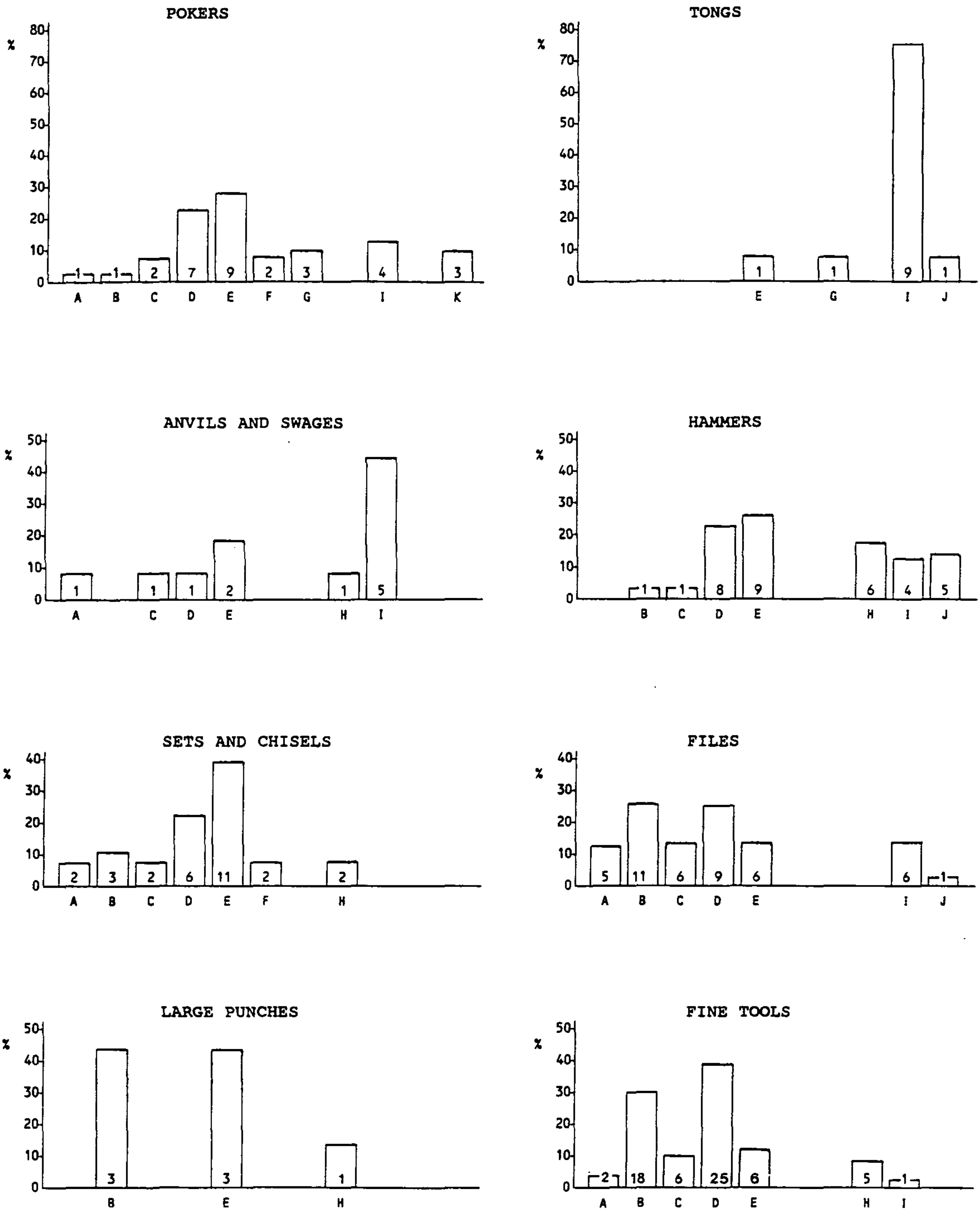
The frequency of the individual categories of tools in different types of archaeological contexts are compared in Figure 5:11. It is noted earlier (Fig. 5:9) that 24% of the tools from occupation sites were found in metalworking areas and debris dumps. The commonest categories of tools with metalworking associations are files (50%), large punches (43%), and fine tools (41%). No doubt this is in part due to recognition on account of their associations, and a distinct bias in numbers is accepted for the Gussage All Saints and Weelsby Avenue assemblages (which were available for examination by X-radiography and additional work).

5.7.2. Tools in 'metalworker's hoards'

Groups of metalwork which include metalworking tools are usually considered to have belonged to metalworkers if scrap metal or unfinished items are present, and to craftsmen in particular where there is a range of specialised tools (Rowlands 1976, 100; Bradley 1982; but see also Barrett and Needham 1988, 138).

Metalworking tools occur in 'hoards' of metalwork (Sections 5.4 and 5.5 above, and Section 5.7.3 below), but only at Santon (Norfolk), and possibly at Barbury Castle, was scrap metal associated with the tools.

Other groups which have been described as metalworker's hoards contain no tools, for example groups from Ringstead, Norfolk (Clark 1951), Snettisham, Norfolk (Clarke 1954), Stanwick, Yorkshire (MacGregor 1962), Tal-y-llyn, Gwynedd (Savory 1964), Ipswich, Suffolk (Owles 1969; 1971), Polden Hill, Somerset (Brailsford 1975), and Seven Sisters, Glamorgan (Davies and Spratling 1976a). (See comment on the alleged Polden Hill hammer, p. 115 above). Some of these groups may have been collections of items for repair or alteration, or of metal for exchange. These groups are all from the later Iron Age or mid-first century AD horizon. No comparable groups are known to the



A Possible metalworking areas
B Discrete deposit(s) of metalworking debris, probable dumps
C Other connections with metalworking debris
D Metalworking activity at the site but tool(s) unconnected with metalworking debris
E Metalworking activity at the site but associations not known
F From sites with no metalworking debris
G From excavated 'hoards' (possible concealments etc)
H Discoveries: no metalworking debris known from the site
I 'Hoards' away from occupation sites
J Cemeteries
K Possible burial(s) within occupation sites

Figure 5:11 Frequency of individual categories of tools in different types of archaeological contexts (%)

writer from the earlier Iron Age, though tools do commonly occur in Late Bronze Age founders hoards (e.g. *Inventaria Archaeologia*, GB 6, 22, 23, 34, 41 and 43) and other groups such as the Heathery Burn cave deposit (*Inventaria Archaeologia*, GB 55).

The potential number of tools determined from possible metal-workers hoards is eleven (5% of the total catalogued) - from Santon (Nos 41, 42, 85, 136) and Barbury Castle (Nos 47, 75, 208, 209, 210, 213, 227) the latter group uncertain in designation.

5.7.3. Tools in 'ironwork hoards'

Interpretations for the hoarding of metalwork in later prehistory include storage, security, exchange (if complete 'goods' are present), recycling (if broken or unserviceable items are present), and response to economic or political monopoly (Manning 1972, 238-9; Rowlands 1976, 163-8; 1981; O'Connor 1980, 307-9; Haselgrove 1987). Deliberate deposition, which is not always distinguishable from hoarding, may have included disposal, burial for security, and offerings (Manning 1972, 238-9). The latter (discussed in Section 5.7.4 below) may encompass burial rites, transactions, and cenotaph, ritual or symbolic offerings (O'Connor 1980, 307; Bradley 1982; 1985; Fitzpatrick 1984).

Metalworking tools occur in nine groups of metalwork, some of which comprise only ironwork (Sections 5.2.6, 5.4, and 5.5). These may include 44 (19%) of the tools catalogued, or 37 (16%) tools if those from Barbury Castle are excluded (Section 5.7.3 above). Potentially, therefore, these comprise tools from Barbury Castle (Nos 47, 75, 208, 209, 210, 213, 227), Bigbury (Nos 63, 68, 95, and ?93) Bulbury (Nos 56 and 57), Fiskerton (Nos 31, 54, 55, 62, 71, 128, 135, 142, 145, 172), Garton Slack (Nos 1, 5, 38), Hod Hill (No. 59), Llyn Cerrig Bach (Nos 39 and 43), Madmarston (No. 8) and Waltham Abbey (Nos 9, 29, 30, 33-37, 45, 49, 50, 58, 144). Apart from the groups from Garton Slack and Madmarston, any of the other groups may be incomplete. With the exception of the Waltham Abbey hoard, the utilitarian or ritual nature of these groups is far from clear.

5.7.4. Ritual deposits

In certain types of archaeological contexts, particularly wet environments, the burial of groups or single artifacts may have had religious or symbolic significance, or have been markers of veneration (Manning

1972; Bradley 1982; Fitzpatrick 1984). Such deposits are normally considered to be ritual or votive due to potential retrieval difficulties and corrosion, and that some artifacts are broken, bent beyond usable form, or burnt (Manning 1972, 240-1; Bradley 1982, 109).

The groups from Fiskerton, Llyn Cerrig Bach and Waltham Abbey (Section 5.5) were all found in peat; ritual deposition is indicated for the latter group, and very possibly for the others. The Fiskerton and Waltham Abbey hoards comprise almost solely metalworking tools and woodworking tools, the majority of which have evidence of some (though not considerable) wear. Both hoards were probably one-phase depositions, or if not, at least the majority of each hoard was deposited together, comprising therefore both metalworking and woodworking tools. This tends to refute the craftsmen (unless multi-skilled) having deposited the tools. On the Continent, metalworking tools also occur in ironwork hoards from watery contexts (e.g. Teodor 1980), or in a deliberately bent condition (Boudet 1984, pl. 141, 5 and 6).

Ritual deposition is indicated for some categories of finds in certain other types of archaeological contexts, for example currency bars in boundary situations (R. Hingley forthcoming), animal burials in rubbish pits (Grant in Cunliffe 1984b, 543), and agricultural implements, weapons, coins, other artifact categories, and human and animal bones in shrines (Rees 1979, 4; Bradley 1987, 358; Bartlett 1988). From their context or associations, other metalworking tools seem very possibly to have been ritually deposited, for example the three hearth implements found beneath a grain silo pit at Garton Slack (Brewster 1980), and conceivably also the tools found close to possible shrines at Woodeaton (Harding 1972, 64-5; 1987) and at Fison Way (Gregory 1981). The presence of currency bars in the hoards from Madmarston and Hod Hill may indicate ritual deposition for these two groups (cf. R. Hingley forthcoming).

Ritual significance of single artifact depositions can go unrecognised, whether from previously wet environments, occupation sites, or any other type of archaeological context, and may have been not uncommon during the earlier Iron Age due to scarcity of iron (Manning 1972, 241) or as symbolic replacements for burials (Jope 1961a, 321; Fitzpatrick 1984, 183). Unlike chance finds of weapons and other distinctive or elaborate metalwork which are known from wet environments throughout the Iron Age (cf. Fitzpatrick, 1984, 181, tables 12.1

and 12.2), deposits of single tools have not been recognised from watery contexts - perhaps because of their similarity to modern examples (Saunders 1977, 19). The archaeological record may therefore be incomplete with regard to single artifact ritual deposits of metalworking tools (and other ferrous tools) and show a bias towards stylistically datable metalwork and, because of corrosion, non-ferrous metalwork in particular.

Analysis of tool categories according to archaeological context (Fig. 5:11 above) shows that very few pokers, anvils or hammers, and no tongs, have been found in contexts with metalworking connections. Where contexts are known, the following occurrences may be noted:

Pokers

(1) Waltham Abbey: Nos 9, 29 and 30 in probable ritual deposit
(2) Fiskerton: ?poker No. 31 in probable ritual deposit
(3) Garton Slack: Nos 1 and 5 (both complete) below a grain silo
(4) Madmarston: No. 8 in an ironwork 'hoard' (≈ complete)
(5) Billingborough: No. 28 (complete) broken and placed in a ditch
(6) Southcote: No. 6 placed in a pit (complete)
(7) Conderton Camp: No. 7 unstratified (but complete).

To this list may be added, possibly, the three pokers from Witham Bury (Nos 2, 3, 4) dubiously associated with skeletons (but which may otherwise be from one or more of three burials).

Tongs

(1) Waltham Abbey: Nos 33-37 in probable ritual deposit
(2) Llyn Cerrig Bach: Nos 39 and 43 in probable ritual deposit
(3) Garton Slack: No. 38 below a grain silo (with pokers Nos 1 and 5)

Anvils

(1) Waltham Abbey: Nos 45, 49, 50 in probable ritual deposit
(2) Fiskerton: No. 54 in probable ritual deposit

These three categories of tools are unlikely to be lost owing to their size (cf. Schiffer 1976), which may explain their scarcity or absence from contexts with metalworking associations. It has similarly been noted that hammers, tongs, and anvils rarely occur in 'industrial hoards' from the Bronze Age (Barrett and Needham 1988, 138). Of possible relevance is that the Iron Age deposits listed under the three tool categories above are principally from eastern England with three single deposits occurring also in central England (but contra the distribution of metalwork in watery contexts in Wait 1985).

Modes of deposition are unclear for other categories of metalworking tools, though small tools are present in some of the hoards discussed above. Another possible candidate by virtue of its size and context is a hot chisel (No. 98) from a grain storage pit at South Wonston. For those most visible in the archaeological record - pokers tongs and anvils - it seems possible that ritual deposition was not uncommon, and it may be that only certain categories of tools were more frequently deposited intentionally, or at least in certain types of archaeological contexts. However, these large tools - all tools unlikely to be lost or discarded - are also more likely to be recognised during excavation or as chance finds.

The possible symbolic role of agricultural implements has been noted by Rees though not interpreted (Rees 1979, 4). The relationship of deposition of agricultural implements to the production cycle, and the breaking of the cycle, is commented upon by Bradley (1982, 117) and re-stated by others (e.g. Barrett and Needham 1988, 135; Barrett 1989, 315; Gosden 1989, 378).

Metalworking tools also may have had symbolic roles in a production cycle. A utilitarian interpretation is generally preferred for metalworking tools found in metalworking contexts, namely loss or discard within the 'industrial' context, unless any are found in a deliberately bent, snapped or otherwise mutilated condition, or there are other indications. The largest group of metalworking tools from a single feature - twenty-one from pit 209 at Gussage All Saints - justifies a brief analysis. Such a large number of tools is surprising even in $3m^3$ of compacted waste (Spratling 1979, 125). At present, there is no means of knowing if the incidence is normal or exceptional, and furthermore that the number is probably biased through means of examination (p. 276). A large proportion of these tools are complete, with the principal exceptions being fragments of five files (the category of tool most readily determined by X-radiography, see p. 135 above). Possibly the high incidence of tools is due to loss during clearance of a metalworking area, or discard after damage for certain tools. It would seem that the recovery and recycling of waste metal was not important (Section 5.2.1), for whatever reason, and the tools could have been similarly abandoned, constituting therefore *de facto* refuse (cf. Schiffer 1976). Or were some of the tools in this group deposited symbolically - in veneration of skills or products, or as inducements for skill, or sacrificial markers in or at the end of the production cycle?

The metalworking tools which seem very probably have been ritually deposited are 25 (11%) from the hoards from Fiskerton, Llyn Cerrig Bach and Waltham Abbey. Others with very possible ritual connections may account for another eleven or more (listed above), but potentially may include almost any tool catalogued.

5.7.5. Tools in burials

The tools from the five certain burials are five hammers, tongs, and a file, and from possible burials there are three pokers. Two of the burials (Rudston Burial 154 and Whitcombe Burial 12) each contained two metalworking tools and also a sword and other weapons which suggests that the graves had metalworking connections and possibly were burials of high social status.

Only a few burials in Britain have contained other types of craft tools or implements for domestic or agricultural use. Whimster (1981) has catalogued three woodworking tools, four agricultural implements, nineteen knives, one pair of shears, two loom-weights and a bobbin as grave goods in Iron Age burials, excluding a few other implements which occurred in upper fills of graves and items of doubtful Iron Age date (and therefore dubious Iron Age burials). To this list can be added a further nine knives, two pairs of shears, two needles, and a punch (Table 3:9) from King Harry Lane (Stead and Rigby 1989, 104-7). From Rudston, there is an awl (Table 3:10), a file (Table 3:5, e), hooked blade and two possible other tools (I. Stead forthcoming). Knives and shears may have had domestic or personal uses as well as possible craft functions, and in several of the burials the former seem more likely. Thus, burials which include definite craft tools and accessories other than metalworking tools are:

(1) Ham Hill - adze-head (plus a sickle, pottery, dagger and other military items); cremation, *c.* 200 BC (Walter 1923).

(2) Ham Hill - adze-head and tanged chisel (plus an iron ?neck-ring); fragmentary inhumation (Whimster 1981, 239).

(3) Hod Hill, Pit 15b, secondary burial - two chalk loom-weights and a bone bobbin (plus other domestic items); adult female inhumation, 2nd - 1st centuries BC (Richmond 1967, 27, 41, pls 9b and 10a).

(4) King Harry Lane, Burial 134 - needle and punch (plus a brooch and a bowl); adult cremation, AD 40-60 (Stead and Rigby 1989, 107, 306, 310, fig. 112).

(5) King Harry Lane, Burial 270 - needle (plus 4 brooches, an iron buckle, bone belt, and a beaker); cremation, ?female, AD 1-40 (Stead and Rigby 1989, 107, 342, fig. 141).

(6) Rudston, Burial 141 - awl, file, hooked blade (?leaf-knife), and an antler tine in a group; inhumation (I. Stead forthcoming).

Although this list may not be up to date since Whimster's survey (Whimster 1981), it demonstrates that few crafts (other than pottery) are represented in grave groups, and that no tools from a single craft occur as frequently as metalworking tools.

On the Continent, tools which seem likely to be for metalworking also occur not uncommonly in burials. Apart from a few tools in burials of Hallstatt date (Olhaver 1939; Kokowski 1981, table 1; Hodson 1980, 120; Megaw 1985, 173), there are at least forty-six in burials of La Tène period (Taus 1963; Ratimorská 1975; Kokowski 1981, table 1; Megaw 1985, 173), and presumably many more not known to the writer. These latter tools comprise eight hammers, an anvil, ten tongs, twenty files, six chisels or gravers, and a punch. Seven of the tools are from a single burial at Rzadz in Poland, and twelve are from three burials in a cemetery at Wesótki, also in Poland. In addition, from a possible barrow at Celles, Cantal there are twenty-eight tools, mostly woodworking and leatherworking tools, though five or more may have been for metalworking (Pagès-Allary *et al.* 1903). However, Guillaumet considers that this group may have been from a workshop rather than a burial (Guillaumet 1982).

'Smith' burials, where these can be demonstrated by other grave contents to reflect social status, are the principal archaeological evidence for the status of metalworkers (Rowlands 1971, 216). The high status of burials with chariots or weapons, or at least the high status associated with smithing skills, is sometimes perceived to confer high status on craftsmen (Megaw 1985, 172-3; Hodson 1980, 120). However, ethnographic analogies indicate that where high status is attached to smithing skills, the tools, or the workplace, this need not be reflected in the status of the smith (Rowlands 1971, 217). Tools in burials need not in any case imply that the grave is that of a metalworker since burials with high status artifacts (or associations) may have been a means of achieving or maintaining rank (Bradley 1982, 120).

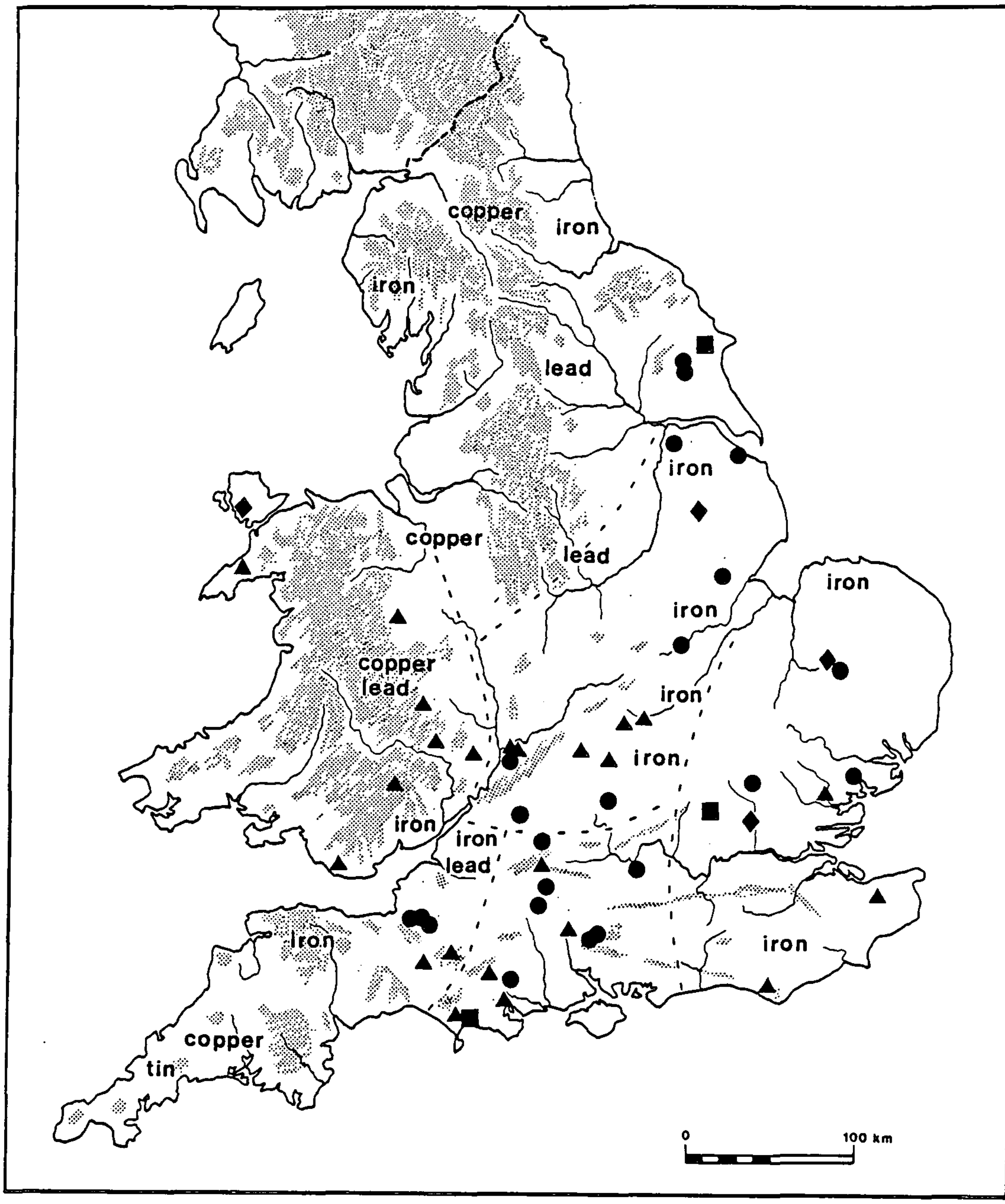
Classical sources (e.g. Pliny, *Natural History* IX, 33 and 34) indicate mystique attached to metalworking, in particular to transmutation of ores and metals, and in the contents or use of recipes for joining and colouring metals. Often similar concoctions were used for medical purposes, as also were residues from metalworking (e.g. Dioscorides, *Herbal V*, 89, 90, 94, 97, 101). The "doctor's" at Obermenzing, Bavaria (de Navarro 1955), a cremation which included three surgical instruments and a sword in a *chagrinage* decorated iron scabbard, is an obvious candidate of a high status burial. Another burial from the same cemetery contained a ritually bent spearhead. The mystical and the ritual nature of burial practices may not, therefore, be easily distinguished, nor can the occupants of graves containing metalworking tools necessarily be assumed to be craftsmen (or metalworkers). Nevertheless, their presence in graves does tend to suggest either personal possessions, or a symbolic, ritual or magical connection with metalworking - whether as markers of social status, wealth, or veneration.

5.7.6. Geographic distribution of the tools

Figure 5:12 shows the geographic distribution of the presumed and possible metalworking tools and indicates the location of the main ore deposits which may have been exploited during the Iron Age.

The frequency of the tools recovered from occupation sites (84.5%), 'hoards' unassociated with occupation sites (12.5%) and cemeteries (3%) are shown by region in Figure 5:13. The six regions considered (indicated in Fig. 5:12) are not equal in area nor in archaeological activity, and there may be an archaeological bias in the number of tools from Wessex which has not only been more intensively excavated as a region (Cunliffe 1984a, 12), but includes Gussage All Saints which yielded 17% of the total number of tools catalogued.

Metalworking tools are determined in this study from 23 hillforts and from 22 settlements (Oare counted as a settlement though this is uncertain), but fewer metalworking tools have been recovered from hillforts (87 tools) than from settlements (108 tools). Although there is evidence of appreciable metalworking activity at hillforts



● Settlement

▲ Hillfort

■ Cemetery

◆ 'Hoard' unassociated with settlement

Land over 183m

Figure 5:12 Map showing main ore sources and the distribution of the sites and hoards with metalworking tools

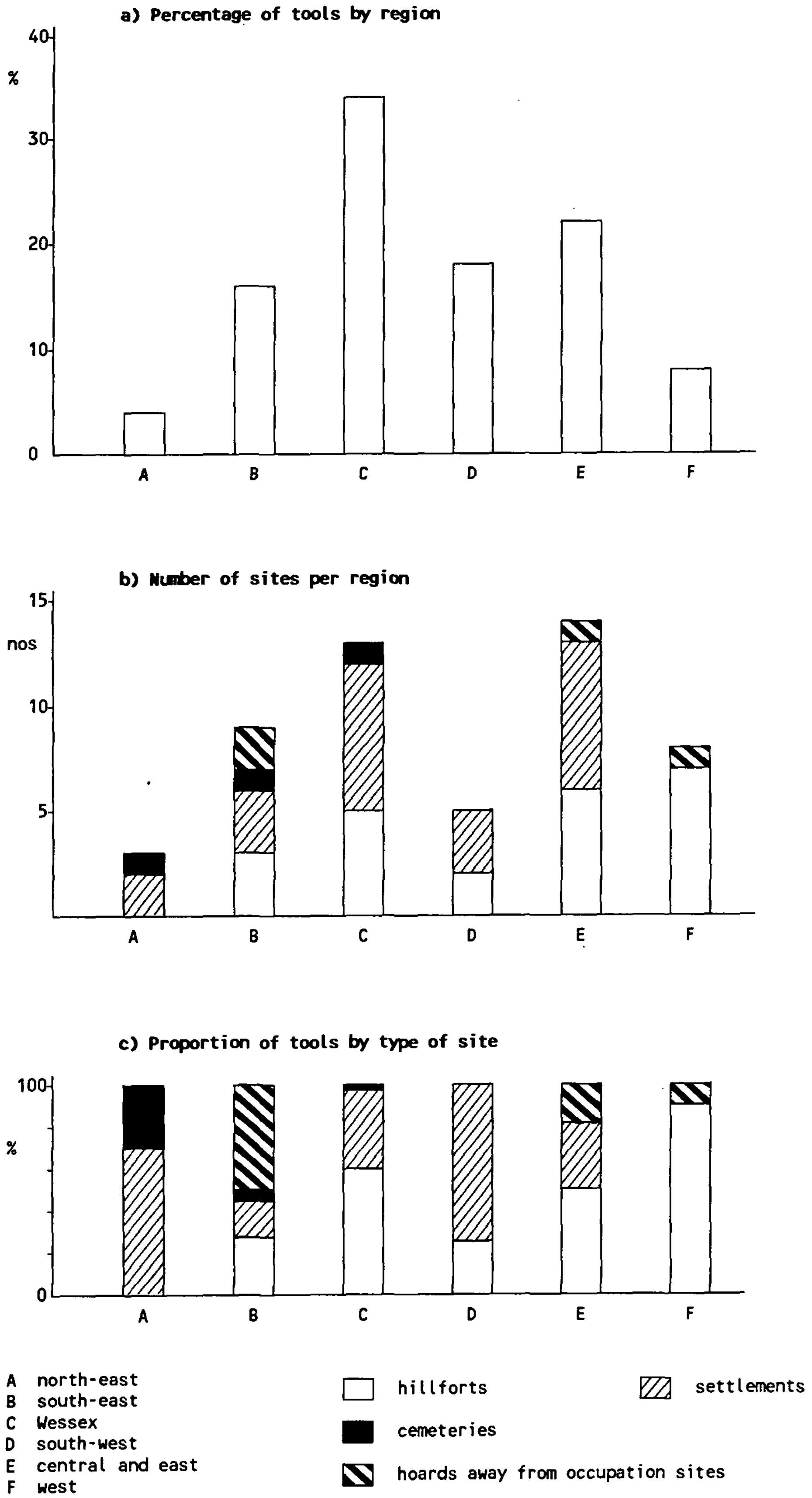
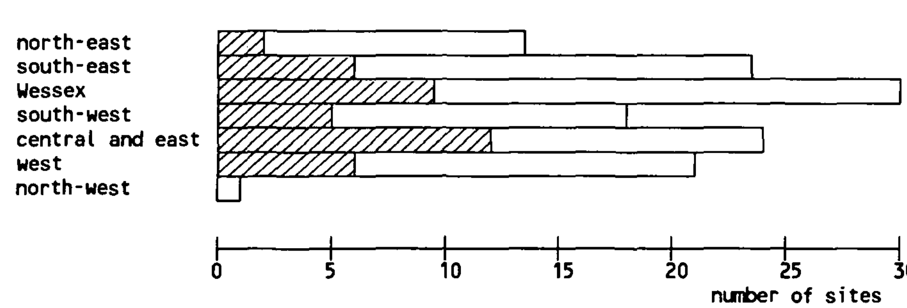


Figure 5:13 Distribution of tools by region

such as Danebury, Hengistbury Head and Hunsbury, there are indications of equally or more intensive activity at low-lying settlements (mostly enclosed settlements). The latter includes the rural settlements at Gussage All Saints and Weelsby Avenue, and extensive sites such as Beckford, Fison Way, Glastonbury and the Meare villages. There is, however, likely to be a bias in the retrieval and recognition of ironwork from more recently excavated sites, and therefore these figures probably reflect the types of sites excavated (of which settlements predominate in more recent years).

In order to test potential bias in recovery of tools geographically, the regional distribution of sites which have yielded certain or probable debris from either smelting or the manufacture of metalwork are plotted in Figure 5:14. In general, the regional trends are similar to the distribution of metalworking tools except that there is proportionately a slightly greater number of sites in the north-east and possibly in the south-east and Wessex where there is evidence of metalworking but tools have not been found. Known iron-smelting sites are located predominantly in the south-west, Wessex, central England and the west (Tylecote 1986, table 72), which probably accounts for this discrepancy rather than archaeological or survival factors. However, these figures take no account of the date of the metalworking activity, cultural trends, or type or status of the sites.

Figure 5:14. Distribution of Iron Age metalworking debris by region



Total 130 sites

sites with metalworking tools — sites without metalworking tools

Sources: Tables 5:9 and 5:10, with additions from Tylecote 1986, table 72

5.7.7. Chronological distribution of the tools

A few of the metalworking tools are from fifth and fourth century BC contexts; two each from Gussage All Saints (Nos 188, 194) and Danebury (Nos 183, 219), and one from Castle Yard (No. 20), Groundwell Farm (No. 117), and possibly one from Rainsborough Camp (No. 96). Others which are potentially early are those from Fiskerton and Hunsbury.

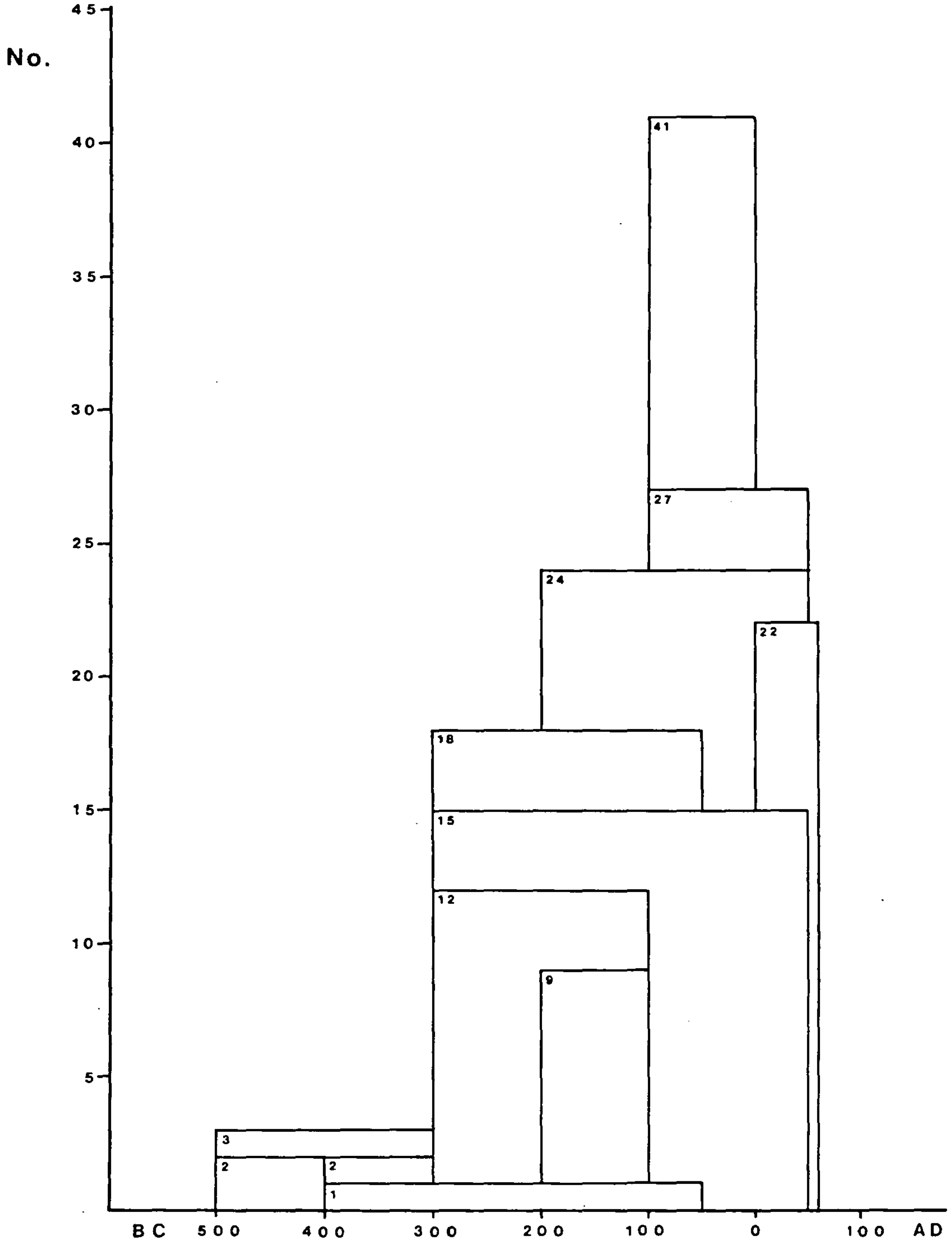
The majority of the tools are from the later Iron Age; ninety (39%) have probable first century BC to mid-first century AD contexts or associations (Figure 5:15). Some may be later, such as those from Bulbury, Waltham Abbey and Wetwang Slack, or may be Iron Age types whose manufacture or use continued into the first or second decade of the Roman period (from Oare and Gussage All Saints phase 3), or indeed may be Roman including those from Bagendon and Santon, and some from Ham Hill and Hod Hill. The latter possibility cannot be excluded for many other tools from the first centuries BC/AD. Tools dated from associated non-utilitarian metalwork (cf. de Navarro 1972, 331), or from pottery according to pre-war chronologies (cf. Swan 1975), seem least likely to be correctly assigned.

For 24% of the tools there is no clear dating evidence; 14% of the tools are discoveries from occupation sites, and in other cases the archaeological evidence has not provided any secure dates. Excluded from Figure 5:15 are therefore unstratified tools, and tools from the Caburn, Fiskerton, Twyn-y-Gaer, and Wetwang Slack.

The earliest occurrences of tools are from the south of England (3 sites) and Midlands (1 site) with other potentially early occurrences from the Midlands and east (3 sites). Given the limitations in the dating evidence of some of the groups, there would appear to be no particular geographic trends in the chronological distribution of the tools.

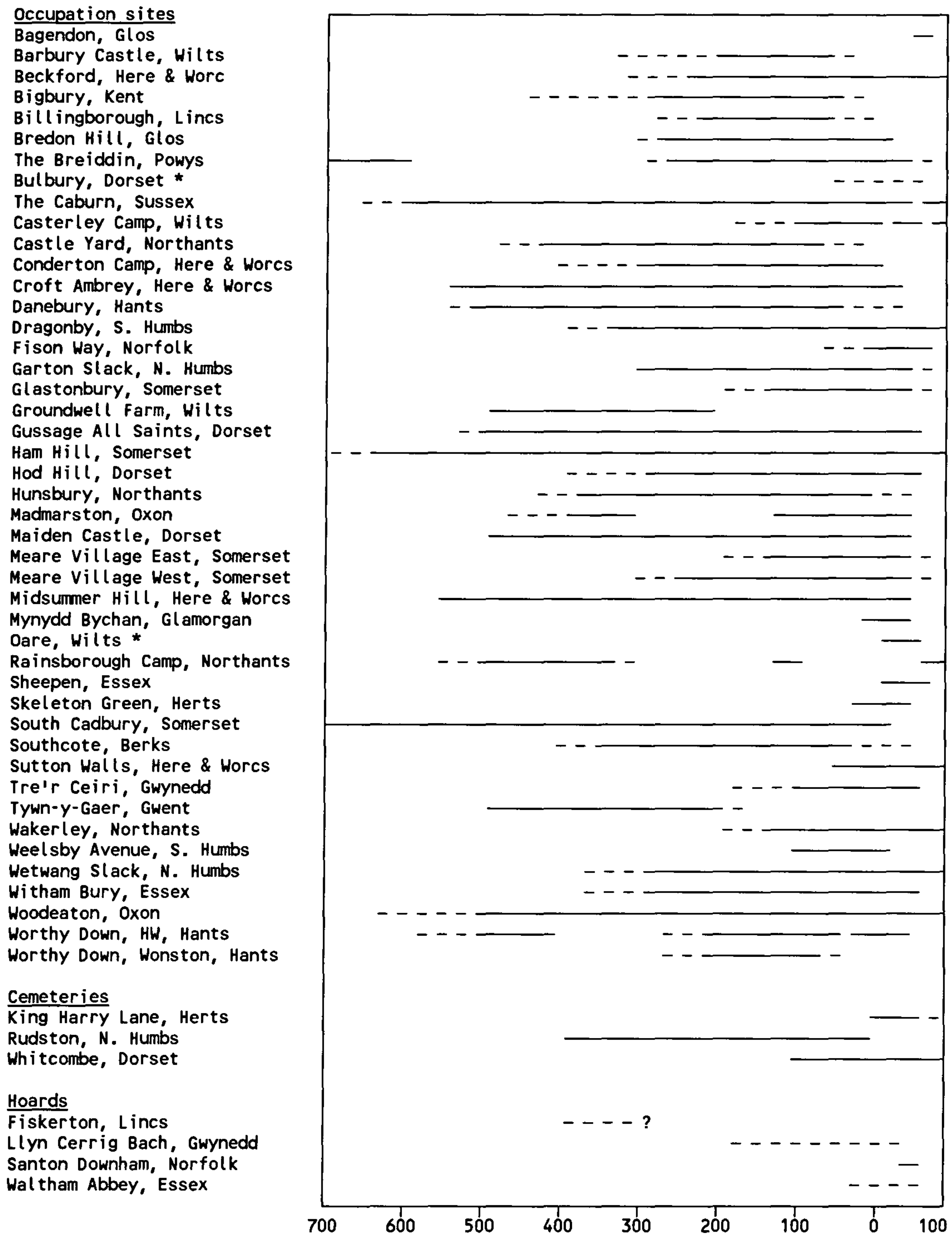
None of the sites with evidence of earlier Iron Age metalworking activity, for example All Cannings Cross, The Breiddin, and the midden at Potterne, has yielded metalworking tools from early contexts.

The periods of Iron Age <u>occupation</u> of the sites with metalworking tools and the date <u>ranges</u> of hoards and cemeteries (Appendix C) are shown in Figure 5:16. The majority of sites were occupied in the later Iron Age with occupation generally extending into, or later



Unassigned 24%

Figure 5:15 Chronological distribution of the tools



* no clear occupation date range (date applies to the group of finds or single feature)

Figure 5:16. Period of occupation of sites with metalworking tools, and date of deposition of hoards than, the first century AD. Some sites were founded considerably earlier, though occupation was not necessarily continuous. Moreover, very few of the sites have been examined sufficiently thoroughly to demonstrate continuity of occupation.

The evidence discussed earlier for metalworking (Sections 5.2 and 5.3), and in particular for ironworking, comes mainly from the later Iron Age though to some extent this is a reflection of the sites which have been excavated. The quantities and dating of tools from selected individual sites and cemeteries are shown in Figure 5:17. In general, the occurrences of tools corroborate increased metalworking activity during the middle or later periods of Iron Age occupation of individual sites, but also reflect an increase in the number which were lost, deposited, or abandoned (cf. Cunliffe 1984b, 556), and accords with changes in burial practice (cf. Whimster 1981) and deposition of ironwork hoards (cf. Manning 1972).

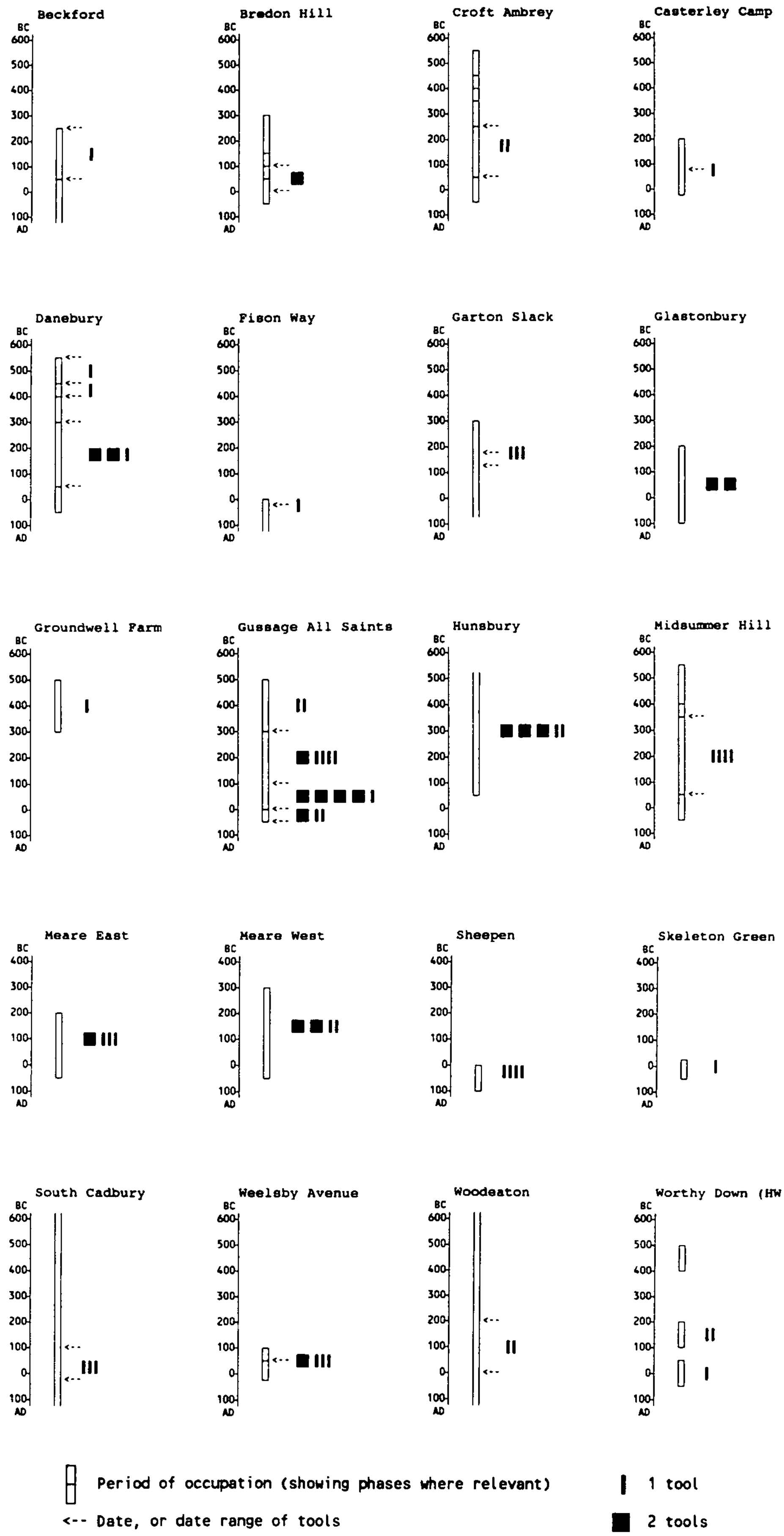


Figure 5:17 Quantities and dating of tools from selected sites

CHAPTER 6

SUMMARY, INTEGRATION, AND RETROSPECT

The primary aims of this study are to identify and characterise Iron Age ferrous metalworking tools, and to examine their archaeological occurrence. In order to determine purpose and attribution of the tools, the following aspects are examined: the metals and metalworking techniques employed, the properties of metals and tools, the waste materials and other indicators of metalworking activity, and functional and social use of tools. This chapter summarises and integrates the principal findings.

6.1. The metals and metalworking techniques

During the Iron Age, metalworking in Britain embraced many techniques known in the Bronze Age, and in addition, ironworking from the eighth or seventh centuries BC, *cire perdue* casting from the third or second centuries BC and possibly earlier, and coin production from the late second century BC (Chapter 1).

Iron-smithing involved new working methods and skills by virtue of the metal normally being shaped by hot-forging. The smelting of iron involved solid state reactions; the process was less easily controlled than the smelting of non-ferrous ores, and produced blooms heterogeneous in composition.

The adoption of ironworking in Britain may have been due to a number of factors including disruption in trade mechanisms and other economic or political systems, changes in social and subsistence roles (Scott 1978; Rowlands 1980; Alexander 1981), and the presence of readily available ores at a time when bronze was scarce as a consequence of these changes (Thomas 1989). The rapid manufacture and repair of items which iron-smithing made possible may account for its continued and probably increased use during the later Iron Age, and no doubt the technological benefits were realised by at least some metalworkers.

Cire perdue casting, dependent on newly acquired and developed skills as well as available raw materials, enabled the manufacture of more complex items than could be produced in open moulds, and probably also more rapid production than by wrought techniques, despite the moulds not being re-usable. Casting, however, involves very little working of metal, being a process concerned mainly with refractory accessories and metal melting.

Wrought non-ferrous metalworking, employing skills pertaining to the intrinsic 'plastic' qualities of the metals, continued in use for both prestige and domestic items, but in more diverse and intricate forms than employed in the Late Bronze Age.

New techniques and styles were employed for the decoration of metalwork. At the beginning of the Iron Age, designs were simple and largely comprised chased lines, embossed domes, and cast decoration. Line and tremolo engraving is known on metalwork from at least the fifth century BC in Britain, whereas true *repoussage* seems to have been a slightly later innovation (Chapter 3.10). Some designs and techniques were insular developments, for example high-relief *repoussé* work such as the 'crested wave' (Spratling 1972; Jope 1976), and hatched 'basketry' - which was normally engraved (Lowery *et al.* 1976).

Jacobsthal, in his survey of continental art styles, comments that the principles of the 'Plastic Style' were later 'brought to perfection ... in the arts of Great Britain and Ireland' (Jacobsthal 1944, 102). Spratling sees the main technological developments in bronzework in southern Britain occurring from the first century BC with occasional evidence from the second century BC or possibly earlier (Spratling 1973, 361). The innovations apparent in surviving bronzework are mainly in the scale and variety of products (Spratling 1972) for which Spratling attributes continental influence in style of artifacts such as weapons and vessels, but very little influence on items presumed and alleged to be connected with chariots (Spratling 1972, 359-60). From the latter part of the Iron Age, standardisation or mass-production is apparent in some types of artifacts or in the techniques employed.

From surviving finds, iron seems to have been less frequently decorated than non-ferrous metals, but this may well be due to the failure to recognise decoration owing to corrosion effects. However, since some techniques (such as *repoussage* and chasing) require frequent annealing of the metal, it is possible that the rapid oxidation of iron (producing scales which are stubborn to remove) was a deterrent to the common use of certain decorative techniques. Other technological reasons may have also been responsible, as may cultural factors.

6.2. The tools

The increased range of wrought products and of more complex decorative techniques which were used during the Iron Age required a broader range of tools. The metalworking tools determined from the Iron Age are made principally of iron. The known exceptions are two copper alloy formers (Spratling 1970a), and an anvil and hammers in stone (Fox 1954; Crew 1987; 1989). It is possible that other types of stone tools may have been used, for example burnishers, as well as tools made in organic materials such as hard wood, bone, or antler. The latter may have included tools such as mandrels, stakes, swages, mallets, formers, burnishers, and certain types of punches. Not very many tools made of organic materials and suitable for metalworking have survived or have been recognised from the Iron Age, and the few which may have been connected with metalworking are mainly implements which were probably used for modelling wax for *cire perdue* casting.

The iron tools

The tools made of iron are the principal subject of this study. Attribution is assisted by inference from structural forms of products and tool marks, and sometimes from archaeological associations (see below p. 308-9). Techniques assumed from tool marks include engraving, chasing, scoring, and wheel polishing, whereas techniques assumed from structural form include casting and *repoussé work*, and from a combination of form and tool marks may be included iron-smithing, coin striking, and stamping of metals. Since it is possible that Iron Age metalworkers may have commonly employed techniques and tools for which there are no known analogues, it is unlikely that the full range of tools will be realised even, conceivably, if the tools are found in contexts with solely metalworking associations. The tools discussed are therefore those with presumed and possible metalworking purposes - those which have survived and have been recognised - but are probably only a small proportion of the total and of the range employed.

The catalogue (Appendix A) comprises 231 iron tools, though a few are of uncertain attribution (see pages 92, 118, 126 and 145). Additional tools of uncertain identity or date are listed or noted in Chapter 3 (see especially p. 90 and Tables 3:1, 3:4, 3:5, 3:9 and 3:10). A number of the tools catalogued are intrinsically for metal working, for example anvils and swages. Some tools are characteristic of specific techniques and thus the probable metal species on which they were intended, for example long-handled chisels and punches for iron-smithing. Other tools, such as sets, cold chisels and hand hammers, cannot be so readily attributed to the working of any particular metal species, nor necessarily to a metalworking function. Hearth implements and some of the decorating and finishing tools cannot be assigned to a specific craft with any certainty.

Factors which contribute to the difficulties in identification of early tools, especially small tools with fine working edges, include condition, wear, modification, and possible differences in manner of use (Chapters 2.4 and 3.10.1). Specific to tools made of iron is the problem of corrosion, both in the ground and after excavation, and the present condition of the iron tools has not always aided examination and identification. Nevertheless, careful examination of assemblages, assisted principally by X-radiography, has enabled the determination of a greater number of tools than previously known.

Tools recovered from waterlogged environments, particularly those in the hoards from Waltham Abbey and some from Fiskerton, have provided many of the best preserved examples, and this has allowed greater potential for characterisation. Others from Fiskerton which had not been continuously waterlogged, as well as many of those from the intermittently waterlogged sites of Glastonbury and the Meare villages, were recovered as totally mineralised or even voided artifacts, but as a consequence, stable and little altered since excavation. It seems likely that other tools from these latter sites were too corroded to recognise as artifacts, or too fragile to recover.

The vast numbers of worn whetstones found at Glastonbury and the Meare villages which were likely to have been used in the maintenance of iron tools and implements for agricultural, industrial, and domestic purposes, suggest that the quantity of ironwork found at these sites represents only a very small proportion of the total. Although many of the iron tools were probably used for constructional and agricultural purposes at these sites, the presence of residues indicates significant metalworking activity during some period of occupation, and it seems likely therefore that many metalworking tools have not survived. However, the Glastonbury and Meare villages are anomalies in terms of settlement type and may have been industrial complexes with a variety of different activities (Clarke 1972; Orme *et al.* 1981; Henderson 1985; Coles 1987; Northover 1988), and thus not typical of other contemporary settlements.

Chronological range of the iron tools

The chronological range of the metalworking tools discussed extends from the fifth century BC to the mid-first century AD, though a small proportion may be later (Figure 5:15). There seems to have been a general increase throughout the Iron Age in the number which were lost, discarded, or intentionally deposited; 39% are assigned to the first centuries BC/AD though many more may belong to this period. In general, the distribution corresponds with increased metalworking activity during the middle and later periods of occupation of individual sites (where this can be demonstrated), and accords with an increase of deposits in ironwork hoards (Manning 1972), and changes in burial practice (Whimster 1981).

Only a few categories of metalworking tools seem to be distinctively Iron Age; the hammers are distinguishable by the form of the eye from those of Roman date (cf. Manning 1969), though not necessarily very different from those of medieval (cf. Goodall 1980) and later date (cf. Salaman 1989). A distinct type of angled hammer occurs in the last century of the Iron Age in Britain, and this type very probably reflects continental influence. The spatulate-ended long poker seems also to be characteristically Iron Age, though like the hammers, occasional examples may be quoted from the Roman period.

Typological range of the iron tools

The range of iron tools from Britain includes examples of most types for which techniques assumed from structural form and tool marks suggest their use. Not included in the range are a few tools which are known from the Continent, for example coin dies (Collis 1985, 103), patterned punches (de Navarro 1972, 190), a compass (Pagès-Allary *et al.* 1903, 394, fig. 13), possible rivet-punches (Olhaver 1939, 114, Abb. 42), and possible (though very dubious) draw-plates

(Jacobi 1979).

During the European Iron Age, tools were introduced or modified to enable the hot forging of iron (e.g. sledge and set hammers, and hot chisels and punches). Hinged tongs are not known before the Iron Age (cf. Ohlhaver 1939), and these were presumably devised to cope with the increasing needs of iron-smithing, though may also have been used by the non-ferrous metalworker for the annealing of metals, and for many other tasks. Prior to the Iron Age, files are rare and the few known on the Continent were unlikely to have been used for working metals (Ohlhaver 1939). Decorating tools in iron assigned to Hallstatt B are known from central Europe, and tool marks assumed to be from the use of iron chisels may occur on Hallstatt A1 bronzes (Bouzek 1989).

There is no evidence to suggest that any of the tools discussed from England and Wales are British introductions; earlier examples of most categories may be cited from the Continent. Categories of tools which are most likely to be demonstrated to be of British origin are dies, stamps and decorated punches, providing that tool marks from any of these tools which may be found in the future are determined only on products of British manufacture. Conversely, there is evidence to suggest imported tools, namely a coin die inferred from a die link (Haselgrove 1987, 192). Military influence (Manning 1976, 1-3) or cross-Channel social or economic contact (Haselgrove 1987, 193) from the first century BC, or indeed earlier, may have involved exchange or transference of tools as well as prestige 'goods' - but the latter are more readily isolated in the archaeological record. This need not mean a mass influx of iron tools into Britain, but the possibility of imports does exist. In addition, metalworking techniques (and therefore also tools) may have been influenced by imported artifacts whether directly from metalwork or via other crafts (e.g. the wheel for polishing).

The two largest categories of metalworking tools determined from Britain are hammers (34) and files (44). Both categories exhibit a wide variation in form, and these differences are presumably due largely to functional needs. Hammers were presumably modified through experimentation (independently or on both sides of the Channel) but with local adaptations superimposed on any major alterations. The earliest iron hammers recognised from England and Wales are probably those from Fiskerton (Nos 62 and 71) which may date to the fourth century BC, and both are specialised hammers - the former probably for raising and the latter for sinking. Files were also made in a wide range of forms, suggesting that there was a requirement for finishing tools of high quality, though it is an open question whether the range was increased by demand, or if the ingenuity of the tool-maker benefited the bronzeworker. Again, the earliest examples are possibly from Fiskerton, including two files (Nos 142 and 145) with unambiguous evidence (p. 140-2) for their employment on metal (copper alloys).

With the exception of the angled hammer (whose change in form is unlikely to be related to function), no chronological or regional trends can be distinguished. This is possibly because the form of a tool does not alter unless there is a need to improve working properties, or the method of use alters, or if functions become more specialised (Goodman 1964; Manning 1981; Salaman 1989). The apparent conservatism demonstrated in the tools may also relate to the handing down of tools through generations of families, or to the copying of worn-out 'proven' tools. Damaged and worn-out tools seem likely to have been recycled; those of acknowledged quality were probably reformed, either because their superiority was recognised to exist in the quality of the metal, or because of symbolic or magical reasons (Alexander 1981) associated with the use of superior tools.

Manning has similarly demonstrated that Roman tools from Britain also show little development, and that basic forms continue unchanged for centuries, or even to the present day (Manning 1969, 21; 1976, 3-4). A study of Roman tools from central Italy by Gaitzsch was also unable to demonstrate chronological development of individual types of tools, though some probable new types were distinguished, and these are attributed to a greater specialisation within crafts during the Roman period (Gaitzsch 1980, 260-1).

Occurrence of the iron tools

The occurrence of the presumed and possible Iron Age ferrous metalworking tools is as follows: occupation sites 84.5%, cemeteries 3%, groups unassociated with occupation 12.5%.

From occupation sites the break-down is as follows: possible metalworking areas 5%, presumed dumps of metalworking debris 19%; other possible metalworking connections 9%; without recognisable metalworking associations 33%; unstratified and other 33% (Fig. 5:9). Thus, 28% of all the tools have probable or possible connections with metalworking residues.

The largest number of metalworking tools identified from any one site is from Gussage All Saints where metalworking dumps in two features (pits 209 and 437) of the same phase of settlement yielded 28 of the 39 tools from the site.

Tools are made primarily for utilitarian purposes though deposition may reflect ritual use (Manning 1972; Bradley 1982; Fitzpatrick 1984; Megaw 1985). Those for metalworking may have had magical or religious associations (Megaw 1979; Alexander 1981). Tools may also have had special significance in production, and deliberate deposition may relate to the breaking of a production cycle (Bradley 1982; Gosden 1989) or other social significance (Bradley 1987; Barrett 1989).

Iron is presumed to have been a valuable commodity during the Iron Age, and one which was normally recycled (Saunders 1977; Manning 1981; Cunliffe 1984a). In any case, metalworking tools - at least those used by ironworkers - seem unlikely to have been discarded if damaged or broken. The occurrence of ferrous metalworking tools in certain types of archaeological contexts may therefore indicate social use, either of the material (iron) or of the tools themselves.

Ritual deposition is indicated for the hoard of metalworking tools and woodworking tools from Waltham Abbey by virtue of many of the tools having been bent beyond usable form (Manning 1980). The group of tools from Fiskerton were probably ritually deposited, as were also the tools in the deposits from Llyn Cerrig Bach. These three groups were found in watery contexts - situations which have had ritual connotations throughout later prehistory (Manning 1972; Bradley 1982). Intentional, and very possible ritual deposition is indicated for metalworking tools in other archaeological contexts, of which the most visible in the archaeological record are large tools, and in particular pokers (Chapter 5.7.4). Although there is considerable bias in the recognition of tools from most archaeological contexts, at least 11% are from probable ritual deposits and a further 2-3% from very possible ritual deposits. Interpretation of many of the 'hoards' of metalwork is difficult, but it is probably a safe estimate that 28%, or more, of the known ferrous metalworking tools are from hoards, ritual deposits, and burials.

Technology of the tools

Despite little typological development apparent in primary tools from the Iron Age and from later periods, it could be expected, however, that they may have been modified in terms of their metal structure and working properties. Edge tools ideally require hardness, durability, strength and toughness - properties relative to the precise function of the tool as well as the nature and temperature of the work-piece and other factors (Chapter 1.8).

The use of steel (whether by chance or intentionally) to provide enhanced properties is demonstrated in many of the Iron Age metalworking tools (Appendix B). The metallographic evidence suggests that the metalworking tools were manufactured from blooms or billets selected for their enhanced carbon content (Chapter 4). Surface carburization is rare, but there is no evidence of the piling of surface-carburized components to enhance the carbon content within the tools.

The forty-one edge tools examined by metallography are from fifteen locations in England. Eighteen of these tools had been quenched-hardened: ten hammers, seven fine-cut files and a possible cold set. Differences in function of individual tools probably accounts for selection for quenching, but may also reflect the possibility that the skill was not widely known (Biek 1982, 305-6), or was technically difficult to achieve (Tylecote 1986, 172-3).

Eight further metalworking tools have been sampled by other workers, of which two tools are quench-hardened (Tylecote 1975, nos 283 and 822). From eleven sites in England, the total number of edge tools for metalworking which are known to be quench-hardened is therefore twenty (40% of those investigated by all workers).

Metalworkers may have devised a range of tools to suit many of their needs, but the non-ferrous metalworker and perhaps also the non-specialised ironworker seem less likely to have acquired the skills necessary for complex welding and for heat-treatments. The optimum working temperatures of plain iron and steel are very different (Figure 1:4), and it would have been difficult to judge the best working conditions of heterogeneous bloomery iron.

In the metalworking tools, the welds from pile-forging were cleanly and efficiently carried out, attested by the generally low level of inclusions and, with two exceptions, freedom from decarburization. A number of the low-carbon tools had been quenched from the incompletely austenitized condition suggesting inadequate heating - a situation which could arise if a smith judged the metal to be of higher carbon content.

Although few of the tools may be considered to be effectively hardened by modern standards, since the correct working conditions for pile-forging and for quenching <u>were</u> often attained, demonstrates that a high technical level was achieved in many of the metalworking tools. Moreover, the selective quenching of hammer faces was practised - presumably to maintain a tougher eye. For these reasons, it seems probable that the manufacture of metalworking tools, in particular hammers and files, was a highly skilled and possibly a specialised occupation.

Because few of the sampled tools are closely dated, and also due to the small sample population from any one site and within any one category of tools, no particular technological developments could be determined. For example, two of the potentially earliest tools, Nos 62 and 71 from Fiskerton (mentioned earlier as specialised hammers), were quenched selectively at their faces. Another five typologically similar hammers were also quenched, two of which are from first century BC contexts at Bredon Hill, whereas the others are unstratified from Hunsbury and Ham Hill (Chapter 3.6). Of course quenching is only one indicator of technological development, but nevertheless, employment seems to be related to functional differences in the tools rather than any chronological or geographic factors.

In order to determine if the technology applied to the metalworking tools is similar in other categories of Iron Age artifacts, comparisons are made from published sources. Around 365 Iron Age ferrous artifacts have been investigated by other workers (Table 2:1), of which about 200 of the artifacts can probably be classed as edge tools or implements. The principal differences are:

(1) With the exception of certain other types of tools (e.g. woodworking chisels), in general Iron Age artifacts from Britain are reported to be of low carbon content (e.g. Salter 1984; Ehrenreich 1985, 62-3; Tylecote and Gilmour 1986, 93-106). However, some assemblages indicate significant carbon levels, for example Gussage All Saints (Tylecote 1975), and currency bars from Beckford (Hedges and Salter 1979, 165). Ore source and smelting technique probably account for the

differences (Chapter 4).

(2) Excluding the eight metalworking tools mentioned above (p. 299), only four of the *c.* 365 artifacts are reported to be quench-hardened: two woodworking chisels (Salter 1984, 354, nos 2.46 and 2.48), a sword (Lang 1984, 71, no. 10), and a knife (Tylecote 1986, 152). These are a very small proportion of each category investigated; two of seven woodworking chisels, one of *c.* nineteen swords, and one of *c.* thirty knives. Even if the identifications of some of the artifacts sampled (Table 2:1) are incorrect (which is unlikely in the quenched artifacts), this would merely shift the proportion in the categories to a lower figure. The implications are that only certain categories of artifacts were quenched, as may be expected, but in particular the metalworking tools were hardened.

(c) Techniques such as cold-working, piling of surface-carburised components, and welding-in of steel, occurs occasionally in blades and wood chisels (e.g. Salter 1984; Lang 1987).

The Iron Age metalworking tools from England compare favourably with those from six sites on the Continent (Chapter 4.7). However, in other types of edge tools, principally blades, the continental evidence suggests that a more advanced technology was employed during the Iron Age (cf. Pleiner 1980; 1982).

6.3 The metalworkers

Skills

Iron Age communities may have had access to a non-specialised metalworker for the manufacture and repair of agricultural and domestic items, but it seems unlikely that this person would have had the range of materials necessary for founding (Spratling 1979, 141-4), or the knowledge and skills to perform the more complex tasks involved in wrought and composite metalworking (cf. Alexander 1981).

The skills required for the four main manufacturing processes of metalwork (iron-smithing, and non-ferrous wrought working, founding, and coin production) are each quite different. Accomplishment in any one process to a level which is seen in Iron Age metalwork would not have been easy, in particular because of likely variations in metal and alloy compositions - and thus differences in the working properties. It seems probable, therefore, that the higher-quality products (in terms of the techniques used, complexity, and workmanship) were made by metalworkers highly skilled and specialised in a particular process or even technique, or by groups or families of metalworkers with each member contributing their own skills (cf. Spratling 1972, 355).

Specialisation

Specialisation need not imply full-time occupation particularly if demand or other economic or social factors limited the time available for production (Rowlands 1976, 115-6; Welbourn 1985, 126-7). Nevertheless, the proficiency demonstrated in Iron Age metalwork, in wrought working in particular, suggests that many metalworkers had devoted a considerable period of time in acquiring the experience and skills. Furthermore, the two social levels of ironworking during the later Iron Age suggested by Alexander (1981), dependent on ore sources and skills, may perhaps be paralleled in bronzeworking - the resources (e.g. refined metals, and either specialised tools, or beeswax and clay) not readily obtainable for local 'low-prestige' use, and the skills not acquired or mastered.

Organisation of metalworking

Metalworking, and specialisation, was not necessarily supported by large populations (Rowlands 1971; Alexander 1972). The indications are that hillforts did not always serve as exclusive 'central places' in terms of production of metalwork, but that metalworking was carried out on a large scale at a variety of sites, including small and possibly undefended settlements (Chapter 5).

The foci for metalworking may have shifted temporally which could account for the proximity of some of the sites with known metalworking activity. For example, the settlement at Beckford (Britnell 1974) has yielded evidence of a greater range of metalworking and more intensive activity than the three adjacent hillforts (Bredon Hill, Conderton camp, and the Knolls on Woolstone Hill). However, occupation at Beckford preceded and lasted for longer than occupation at Bredon Hill (Hencken 1938) and Conderton Camp (Thomas 1959), and in addition, Beckford has been more intensively excavation. Factors such as localisation of expertise, trade networks, and accessibility to raw materials including fuel, may have been important influences on the spatial distribution of some production sites. Common politico-economic control may have regulated coin production at Ditches and Bagendon (Trow 1988, 39-40), or the transfer of control within and between St. Albans (Saunders 1982) and the Braughing complex (Partridge 1981; 1982; Haselgrove, in Potter and Trow 1988, 25; Trow 1988).

Evidence from possible major production sites such as Weelsby Avenue, where ceramic evidence indicates that the metalworking debris accumulated over a decade (Chapter 5.2.2), and Beckford, where metalworking spanned two or more centuries (Chapter 5.2.6.d), suggests that metalworking was not organised on a casual basis.

The rapidly accumulated debris in a single pit at Gussage All Saints may, or may not be the waste from itinerant founding (compare Spratling 1979 and Foster 1980), but there is evidence for considerable iron-smithing throughout one or more centuries, and possibly throughout most of the settlement's existence. In addition, although the evidence for wrought bronzeworking is not considerable, particularly when compared with the evidence of founding, it is nevertheless equal or greater than on any other Iron Age occupation site, with the distribution of the debris and the tools (Figs 5:1, 5:2, 5:3) suggesting activity during all three phases of settlement.

On the basis of the range and quantities of raw materials required for *cire perdue* casting, Spratling has argued that the production of chariot and harness fittings at Gussage All Saints was not a casual event, but that the metalworkers were specialists, who may have supplied the immediate locality in exchange for other goods (Spratling 1979, 141-5). The members of this family unit (Jefferies in Wainwright 1979, 15) or several families (Collis 1982) were arable and stock farmers who also may have traded surplus from these activities, in addition to acquiring the necessary raw materials for the metalworking industry (Wainwright 1979, 188-91).

A similar fixed existence is suggested for specialist metalworkers of the Middle Bronze Age on the basis of the necessary tools and workshop (Rowlands 1976, 164). It may be relevant that ethnographic data supply few analogies for itinerant metalworkers other than for local travel to repair or sell implements (Rowlands 1971). Nevertheless, these analogies do not mitigate the possibility that non-specialised metalworkers in the Iron Age may have led peripatetic existences for the purpose of repair and replenishment of agricultural and domestic implements. This would agree with a two-tier social system of ironworking (Alexander 1981) which to some extent may be supported by the general low-quality of agricultural implements (Ehrenreich 1985, fig. 4.3).

6.4. Metalworking sites

The distribution of artifact types, and stylistic affinities, in general do not enable common workshops to be identified (Rowlands 1971; Collis 1977; Fitzpatrick 1984), nor production sites to be located (Spratling 1972, 346-7).

Metalworking residues at occupation sites provide the principal evidence for production sites. Waste materials are the prime indicator of metalworking activity, whereas tools, intermediate products, and unused metalworking accessories are not necessarily indicative that metalworking occurred in the vicinity of their context. Nevertheless, tools found in association with metalworking debris support the evidence for the location of metalworking areas (e.g. at Weelsby Avenue) and may indicate the nature and complexity of the processes involved (e.g. at Gussage All Saints).

Intermediate products (as opposed to some part-manufactured items) may be metal in transit, and deposition need not necessarily have been related to functional use - as for example currency bars (R. Hingley forthcoming) - at least if these were metal stock or blanks. Nor were clay accessories such as crucibles, investment moulds, and 'coin pellet' moulds necessarily made at the area (or site) where they were to be used (cf. Haselgrove 1987, 29).

On the basis of the distribution of metalworking debris, it appears that the working of iron and non-ferrous metals may have occurred on a roughly equal basis in terms of the number of sites involved, and that at a large proportion of sites, both iron and non-ferrous metals were worked (Fig. 5:10). There is, however, a bias in the range of sites excavated and in the level to which metalworking residues have been recorded and analysed (Chapter 5.3). The archaeological evidence has seldom enabled the chronological extent or the scale of the activities to be determined, nor if the metalworking activities at any one site were concurrent. The technological determination of metalworking debris is often inconclusive or ambiguous, leading to interpretive problems in the precise nature of the metalworking activity. This applies in particular to the characterisation of ironworking slags, and also to crucibles and solidified waste metal and dross - which occur as residues from all non-ferrous manufacturing processes. Furthermore, the retrieval and recording of metalworking residues is disparate, notably in the recovery of ironworking residues, yet these require considerable attention if the scale of iron production is to be assessed in realistic terms (Crew 1988b).

At present, the principal evidence for major production sites comes from the small 'farmsteads' of Gussage All Saints and Weelsby Avenue, where the evidence suggests substantial and concurrent ironworking and bronzeworking. Other settlements which may have had major activity are Beckford, and possibly Glastonbury and the Meare villages. Evidence from the hillforts of Castle Yard, Hunsbury, Bryn y Castell and Crawcwellt, attests extensive ironworking though only at the latter two sites can the scale and nature of the activity be realised (Crew 1987; 1989).

6.5. <u>Retrospect</u>

Three aspects of the study are discussed further in this Section: (I) attribution of the tools according to evidence from archaeological context, (II) ferrous technology, (III) organisation of metalworking.

(I) <u>Attribution of the tools</u>

Many of the tools discussed are chance finds discovered during quarrying or other uncontrolled means (21%) or are from antiquarian collections or excavations (22%). Nevertheless, even from controlled excavations, few of the metalworking tools have probable or possible metalworking connections (28% of the total). For example, of the hammers and tongs, the tools which were later symbolic of the metalworker (e.g. Leach 1962; Manning 1976; 1985; Gaitzsch 1980), only one of forty-six was found with metalworking residues (No. 64). In other categories of tools, such as files and fine tools, the incidence is much higher (Fig. 5:11). This may be explained in a number of ways:

1) Small tools were more likely to have been lost (cf. Schiffer 1976); on the other hand, large tools are more likely to be retrieved from waterlogged excavations and as chance finds.
2) Small tools are less likely to have been components of ironwork

hoards if these were deposited for economic reasons (cf. Manning 1972; Bradley 1985; 1987; 1988), and less likely to have been recycled other than during the probable normal sequence of reforming.

3) A greater proportion of certain categories of tools may occur in hoards, ritual deposits, and burials.

4) Sample bias:

   a. Reported chance finds are more likely to include large or unusual tools.

   b. The numbers of (small) tools determined from Gussage All Saints and Weelsby Avenue are more likely to be representative of the full range deposited at these sites due to opportunities and methods of recovery and analysis.

Distributions and are unclear, and furthermore, do not often therefore assist attribution of tools to specific crafts (cf. Chapter 3). Since few correlations can be determined between the more characteristic (and larger) metalworking tools and 'industrial' debris, it may be that a considerable number or even similar proportion of small tools also occur in non-utilitarian contexts but have failed to be recognised (cf. Fig. 5:11).

(II) Ferrous technology

The technology of the metalworking tools seems in general to be more advanced than other categories of Iron Age artifacts including other tools (Chapter 4). Interpretation is hindered by difficulties of characterising artifacts manufactured from bloomery iron, and that few groups of ironwork have been examined for technology.

Understanding of early smithing techniques and the development of ferrous technology may be advanced in a number of ways. Programmes of experimental smelting and forging of the blooms (cf. Crew and Salter 1989), in conjunction with successive metallographic and elemental analyses, should enable the further characterisation of bloomery irons and steels in terms of segregation effects (cf. Tylecote and Thomsen 1973; Tylecote 1990) and working properties during common forging procedures, heat-treatments, and welding (cf. Pleiner 1973). In order to determine typical compositions and technology of to a broad range of artifacts, analyses within and between assemblages should include blooms and blanks where possible as well as finished products of known identity (cf. Pleiner 1962; 1982).

(III) Organisation of metalworking

The distribution of sites with metalworking activity, and the sites with known metalworking tools, reflects an archaeological bias resulting from the types of sites which have been excavated, the extent of excavation, and the recognition and recording of unprepossessing ironwork and metalworking debris. Moreover, many of the sites which have been excavated more recently (and therefore more likely to have been analysed in terms of industry and economy) are low-lying and possibly undefended settlements, excavated as a result of threats from ploughing, drainage, or development. The present evidence is unlikely to reflect the variety, complexity, or extent of metalworking on the full range of site types, the spatial and economic relationships between metalworking sites, nor the industrial, social, and political organisation of metalworking.

The technology and scale of metalworking in the Iron Age may be advanced by future integrated programmes of thorough and systematic analysis of debris and artifacts. In particular, sites which yield an abundance of debris should offer the greatest potential to characterise more fully the technology of individual metalworking processes. On these sites, metalworking may have formed a major part of the economy during some period of occupation, and analysis of the resources available, as well as subsistence and other roles, may indicate the social and economic relationships of the metalworkers in their communities. Examination of this evidence in its regional and broader context may then give indications of the social, economic, and political organisation of metalworking in the Iron Age.