Weapons, Warfare and Society in Britain 1250-750BC

Volume I

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Abstract

This research project was designed as a large scale detailed study of British swords and spearheads, of the period from approximately 1250-750BC.

202 small metallurgical samples and 4 large sword cross sections were examined metallographically. Chemical compositions were ascertained.

Sections of 'sword edge' were prepared and impacted experimentally to reproduce combat damage and the results used to help assess the 499 swords and 485 spearheads, which were measured and examined visually. The results were analysed statistically according to regional and typological groupings.

The distribution of manufacturing characteristics showed significant regional and typological variations and indicate a hierarchy of technical proficiency. Metallographic examinations also revealed a number of weapons which had been burnt. The compositional analyses showed metal being recycled and mixed, although alloys used were similar.

Aspects of typological classification were quantified and regional patterns of distribution were assessed. Patterns of damage confirmed that that the majority of the weapons had probably been used in combat before deposition. There were significant regional and chronological differences in the proportions so used. Patterns of non-combat damage, breakage and depositional context showed that despite evident similarities some highly significant regional, chronological and typological differences existed.

The weapons indicate that warfare was endemic but probably sporadic and low level. Communities appear to have exercised some form of social sanctioning over warriors, in part by incorporating weapons and the concept of war symbolically within their ceremonials. Deposition practices varied with time and locality but many do appear to have been ritual. There were also distinct regional and chronological traditions in the design, manufacturing and pre-depositional combat use of weapons. The evidence points to an escalation in long distance travel and exchange of goods and ideas, increasing contacts between regions, where people adapted the new to their own society.

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1 Introduction

1.1 Aims

The later Bronze Age has long been recognised as a period when a remarkable quantity of weaponry was deposited in Britain and elsewhere in Europe, indeed Parker Pearson has described the 'European Bronze Age' as 'perhaps the first arms race' (1993, 118). However, few authors in recent years have dealt directly with the implications which this proliferation of weapons has for our understanding of society and the role which warfare had therein. This study is intended to address that question in the light of evidence provided, in the main, by the weapons themselves. In particular it is proposed to:

> Establish the typical microstructures of bronze sword and spearhead blade edges and thereby reconstruct the range of techniques used to finish these weapons.
>
> Establish experimentally the typical morphology of combat damage caused by blade on blade impacts and, thereby, ascertain the likely proportions of deposited bronze weapons showing damage consistent with combat.
>
> Analyse the design of, the range of damage exhibited by and the physical contexts of deposited bronze weapons and, thereby, deduce how weapons were likely to have been used in combat and in the rituals which attended their deposition.
>
> Consider the implication of the results in the context of the roles which weapons, warfare and warriors had within society and how they helped to shape that society.
>
> Ascertain whether or not there exist regional differences in the design and techniques employed to make weapons and in the manner of use and deposition of the weapons and assess the results in the context of regional differences in customs concerning and underlying attitudes towards weapons, warfare and warriors.

1.1.1 The Research Programme

This research programme is designed as a large scale investigation of the swords and spears deposited in Britain during the period 1250-750BC.

It will use metallographic analysis of small samples taken from a substantial number of weapons to determine the range of microstructures and compositions exhibited by the weapons of the period. The results of these metallurgical investigations will be used to define the parameters required to produce replica sword 'edges' for impact experiments, intended to reproduce damage caused during combat, in order to provide a means of classifying the damage exhibited by the edges of archaeological weapons. The metallurgical results will also be analysed statistically to determine whether or not chronological and regional differences exist in manufacturing techniques and 'raw materials' used.

A large number of weapons from museum collections will be examined, measured and assessed, using the experimental results, and the detailed results will be subjected to statistical analysis to elucidate aspects of and determine chronological and regional differences in their design, manufacture, deposition and, particularly, in their use.

The results of this programme of analysis will be assessed along with other archaeological and contextual evidence in order to interpret the roles of weapons and warfare within the social contexts of the period.

Although the techniques to be used are not novel, the systematic application of metallography, and especially of quantitative metallography, to a sufficiently large number of samples of prehistoric material to be susceptible to statistical analyses has not previously been undertaken. The replication of microstructure as well as of composition for experimental use, as is intended here, is vital to the experimental outcome, but has often been left to chance in less structured experiments. The production of a full photographic record of the experimental impacts, which will be available for use in assessing damage to other bronze blades, provided that these are similarly produced, constitutes an important part of the study. The interpretation of the results stemming from the metallurgical and statistical analyses within a wider social context is considered to be essential if the study is to be of value from an archaeological perspective.

1.1.2 Interpretation

Archaeologists deal with the relics of material culture and rarely have means to identify individuals or their actions: 'Clearly the individual is not an analytically useful unit of archaeological study' (Barrett 1994, 4). However, there is a certain sterility in the study of social structures, modelled with little reference to the human beings who not only lived within these structures but who formed and constantly re-shaped them to facilitate their own lives and those of their descendants.

It is intended in all that follows to recognise that the lives and beliefs of the individuals and groups forming the society which existed during the period concerned were not simply predetermined by external factors nor by an inevitable 'procession' along a scale of technological 'improvement' or societal complexity but were moulded by 'knowledgeable' choices made, as individuals and in the groups to which they felt that they belonged, by the people themselves (Barrett 1994, 165).

There is a wide range of 'stories' which can be considered when interpreting the past. Each individual, each lineage and each community has a number of stories to tell. They span different time scales and different perspectives - the individual as child or as parent, as farmer, as warrior, etc.; the lineage as descendants of the ancestors, as builders of future prosperity, as defenders of the family honour; the community as keepers of the faith, as custodians of the land, as enemies and allies of other groups - the possibilities are endless.

It is not only the people who have their stories; the land itself has a history during which it has shaped the lives of and been shaped by those who have lived from it, passed through it, fought over it or simply yearned for it. Each artefact, however humble, has a 'biography' of its own (Bradley and Edmonds 1993) which touches and is touched by the biographies of all the people who affect and are affected by that artefact. Those very artefacts which we now study have themselves undergone resurrection into yet another life where they have been recreated as museum pieces and are recreating our own stories of the ancestors (Barrett 1994, 96).

There is, by definition, no such thing as a 'single history. There are programmes of interpretation which have appeared effective' (Barrett, 1994, 169). It is necessary to deal with the evidence which exists and the perspectives which this will determine should be recognised. In some respects we are seeing the 'routinized activities of individuals going about their daily round..-.. a micro-scale record of micro-scale activities' (Shennan 1993, 55). In others we are seeing variation spreading across a time span of centuries or millennia - changes which are often interpreted by 'the reconstruction of social institutions from archaeological evidence' (Shennan 1993, 53) epitomising Chippindale's 'ambitious tendency' (Chippindale 1993, 29).

The evidence which is studied herein has many limitations, not least the almost total lack of evidence for physical context of deposition which, for many of the artefacts, was a direct result of the various ways in which it has been found, the circuitous routes by which it has reached the museums where it is now situated and the lack of recording of most stages in this uncertain progress. Certain aspects of the artefacts' biographies are, however, available via scientific analysis, giving some at least of the 'micro-scale record' mentioned above, and snippets of physical contextual information are available from museum records and antiquarian writings. The long view is provided by the distribution of the material over a time scale of around five centuries and the provenance of the artefacts gives sufficient information to set them many of them within the landscape, which has, in many areas, been exhaustively investigated by others.

The information is interpreted without explicit assumptions about the size of communities, or detailed modelling of prevailing economic and power structures, all of which will have varied over the time and space considered. Where possible the actions of people, such as those who made, those who used and those who destroyed the weapons, have been considered and these actions have been placed within a social context.

Where it was considered to be helpful to interpretation, scientific and statistical techniques of data analysis, ethnographic comparisons and models of social structures have been used in this study but always with the reservation that these are not ends but merely building blocks. It was, for example, necessary to ascertain the weapons' metallurgical composition and microstructure in order to replicate them and the ways in which they would have been damaged so that their physical characteristics could be interpreted. However that interpretation was merely the beginning of the task, necessary but far from sufficient. It helped to provide a framework of evidence for the 'set' within which the people 'acted'.

A preliminary assessment of the available data indicated that examination of the weapons could, in particular, increase understanding of the relationship between social context and warfare and the topic of regionality and it is on these two aspects that the study has been focussed. 'Warfare' is an area from which recent academic studies have shied away and of which few of us have direct experience yet which seems to have been an important part of people's experience during the time when bronze swords were made. It is recognised that the particular area of this study is but part of a decidedly complex whole and that even this area is incompletely studied herein. However, there still appears to be some merit in re-evaluating the available evidence with the intention of establishing a better understanding of how the people, in whom we are ultimately interested, constructed their own realities.

1.1.3 Warfare, Weapons and Social Context

Most modern definitions of war are difficult to apply in prehistory as they, explicitly or implicitly, require the existence of a 'nation' or 'state', while warfare is frequently defined simply as the waging of war. I have therefore followed Sharples (1987) in adopting Ferguson's (1984, 5) definition of warfare as 'organised, purposeful group action, directed against another group, that may or may not be organised for similar action, involving the actual or potential application of lethal force' but would preface this definition with the term 'socially sanctioned' (Mead 1968) to underline the role of non-combatants in supporting those actually or potentially participating directly in warfare.

A weapon could legitimately be defined as any implement capable of use to inflict bodily harm but such a definition must be refined for the current purpose. It is proposed to restrict the definition to include only those implements designed primarily to be capable of inflicting bodily harm when used by one combatant against another. Such a definition must therefore exclude implements, such as axes, designed primarily for a different use and, given the time period concerned, any weapons made from organic materials must also be excluded from consideration due to their failure to survive. Thus the objects of this study are the bronze swords and spearheads of the period.

The extent to which weaponry is treated in a manner which conflicts with strictly economic or utilitarian criteria provides clues as to the relative importance of warfare and its symbolism within society. The most obvious archaeological signs of the place of warfare within the overall social context of the Late Bronze Age are the ritual aspects of the use and, especially, the deposition of the weapons involved in such warfare. The detection of such ritual aspects is therefore vital to understanding the role of warfare within its broader social context and its effect upon that social context. Design for and damage from use of weapons in combat was considered in detail in order to distinguish ritual from utilitarian aspects of the weapons themselves and the nature and context of deposition, where known, was analysed.

1.1.4 Regionality

There are some obvious, and some more subtle, differences in Late Bronze Age weapon typologies within Great Britain. The explanations for these may well be numerous and complex. Among those considered are variations in design, due to differing end use or aesthetic preferences, variations in regional manufacturing techniques and variations in patterns of contact with other British regions and external cultures.

The patterns of Late Bronze Age weapon deposition also vary markedly from region to region, both in quantity and in the manner and physical context of deposition. In particular the quantity of weapons deposited in those regions where metal ores are known to have been available is, counter-intuitively, very obviously lower than in most other areas. If the reasons for deposition are accepted as largely socially determined, this would imply that regional differences in social customs must have existed.

The distribution of sites deemed to be Late Bronze Age 'forts', which, despite their interpretation as 'military' in nature, do not generally feature large deposits of weaponry, tends to favour these areas. Obviously a mountainous landscape does provide more sites which are naturally defended and metal ores in Britain are restricted to the upland regions but the fact remains that the earliest 'hill forts' seem to border the areas containing metal sources known or strongly suspected to have seen Bronze Age exploitation.

The frequency of deliberate destruction of weapons and the deposition of weapons, both broken and whole, in wet places, particularly rivers, also vary markedly from region to region. These variations in depositional practice are considered in conjunction with the biography of the weapons concerned, in terms of their design, manufacture and use.

The four broad geographic areas chosen for the regional subdivision used herein are shown on the map in Figure 1.1.4. They comprise the South and South East of England, covering the South coast and the entire Thames basin, East Anglia, including the East Midlands and South Yorkshire, Scotland and North East England and a Western region covering South West England, the Avon basin, Wales, the Welsh Marches, and North West England. These regions correspond to those used by Colquhoun and Burgess

(1988) when subdividing the largest group of typologically similar indigenous swords (the Ewart Park type). The regions are referred to hereinafter, for the sake of brevity, as the South East, East Anglia, Scotland and the West. Although these regions are somewhat large, the relatively small numbers of weapons available, particularly from the Western regions, meant that they were the smallest areas which could, meaningfully, be examined on a statistical basis.

This regional division reflects the geographical criteria most likely to have affected patterns of contact during the period. Transport in the Late Bronze Age, particularly for goods, was not a simple matter. Although wheeled vehicles were available (Pryor 1998, 116-7), the use of boats is clearly optimal when compared with the alternatives of carrying goods through forests, swamps and mountains. The sea and the rivers were probably the highways of the time, connecting people along their navigable borders both culturally and economically. The importance of the River Avon and the sea routes to the South coast for contacts between the Western areas of the British Isles and the South East and continental Europe in a rather later period has recently been discussed by Sherratt (1996). The 'borders' between the regions chosen were thus largely dictated by the need to preserve within one region the bulk of the navigable reaches of any major river and its coastal estuary

The regions chosen reflect the divide between what are largely highland areas to the North and West, connected via the sea to Ireland and Brittany, and the lowland areas of the South and East, connected via the sea to Northern France. The divide between highland and lowland regions would also have been reflected in their agricultural practices and produce for obvious topographic and climatic reasons. To the extent that the economic basis of life and the immediate landscape dictate settlement patterns and social organisation, it would be expected that in these respects too the highland and lowland areas would differ.

The highland areas of the West were fairly rich in the minerals required for production of copper and, in particular, of tin, while the South East and East Anglia would have had to import their metals. The availability of primary sources in Scotland during the period is far from proven, although there are numerous small scale copper deposits there which, being 'uneconomic', have escaped the geological maps (Ottaway - pers. comm.). Eastern Scotland is likely to have had to import its metal but the South West of Scotland may have provided a contemporary source for copper (Craddock - pers. comm.) and recent surveying activity in Scotland is turning up some surface signs, including hammerstones, of early mining activity (Timberlake - pers. comm.). Although it may have been preferable on some counts to include South Western Scotland in the West, there were very few well provenanced artefacts from this area and such a subdivision would have created difficulties in classifying the substantial number of weapons provenanced only to 'Scotland'.

1.2 Weapon Typology and Chronology

The chronology of the British Bronze Age has largely been developed from typological analysis of the metal artefacts. Bronze Age settlement evidence is relatively sparse throughout Britain but this is to some extent mitigated by the funerary remains, and accompanying grave goods, in particular ceramics, of the Early and Middle Bronze Age. The absence of Late Bronze Age funerary remains has left this period particularly dependent on metalwork typologies for its chronology.

The funerary rites prevalent in parts of Europe during the Late Bronze Age did not result in such a dearth of archaeological evidence as those in Britain. Sequences were thus generally easier to define relatively unambiguously in continental Europe and sequencing of British types has always been heavily dependent on the presence of characteristics seen in continental types. Sequencing has been applied to very localised types, within Britain, as well as to types which are more widely found and the resulting local chronological progressions have usually been related to each other by means of the sequencing of the more widespread types. On the whole the various schemes have been used as building blocks so that, as time progressed and studies multiplied, the complexity of the groupings has increased. Many of the original ideas, especially those concerning the sequence and origins of the various characteristics, have been transmitted directly into the resultant structure.

Weapons have been particularly important in the development of the typologically based British chronology since they tend to have more well dated continental parallels than tools, due to the presence of swords and spears of the period in burial contexts in parts of mainland Europe. Their British counterparts usually appear as single finds or in hoards in contexts such as rivers and fens or buried on dry land, separate from any funerary or settlement remains. In addition weapon types have generally had a much wider geographic presence than most other bronze artefacts and their type names, in particular those of swords, have therefore often been used as general chronological terms. This being the case, it is necessary to outline the weapon typology, in particular that of the swords, in order to tackle the chronology of the period.

1.2.1 Sword Typology

The development of typological grouping of British Late Bronze Age swords started by dealing with them within a broader European context but recognition was rapidly given to the differences between 'native' types and those with obvious parallels on the continent (Colquhoun & Burgess 1988, 7-10). Most of the generally accepted sword types have been named using the site name where artefacts of that type were either first identified or were predominant. Two of these, the 'Wilburton' and the 'Ewart Park' types, which are particularly important in this study, are referred to by their 'type site' names throughout. These names refer not only to the sword types in question but also to entire 'suites' of bronze artefacts which are generally accepted to be chronologically coincident with the sword types and each other.

The basic characteristics by which swords have been classified and the characteristics of different groups of British Late Bronze Age swords are illustrated in Plate 4.2.1, the latter at approximately one sixth of actual size. The various types have, as shown in Plate 4.2.1, been combined into four groupings for the purposes of this study. These groupings are generally held to be chronologically consecutive, although the second group, the Wilburton type, is largely absent from Northern and Western Britain.

The first group of swords contains a relatively small proportion of the known swords but comprises a number of very different types, all of which are generally accepted as being of early date. The second comprises swords of Wilburton type. The third, and very much the largest group, consists mainly of swords of Ewart Park type. The final, very small, group of 'Late' swords consists largely of two different types showing considerable continental influence.

Early Swords

Early swords encompass a wide range of morphologies. Many have clear European affinities and all are undoubtedly early in date, either by reason of these affinities or of the relatively undeveloped nature of their hafting arrangements. A very few have blades with near parallel sides but the vast majority have wide leaf shaped blades, often with a lozenge shaped cross section. Apart from the rod tanged and Ballintober (illustrated first in the first group in Plate 4.2.1) types, with their rapier-like hilts, the remainder have complete tangs and terminals ranging from the vestigial to relatively large (some even have a pommel projection) but narrow. The majority tend to have very high flanges and large numbers of rivet holes, though there are a number with slotted tangs. Many early types have very widely splayed shoulders (such as those of the third and fifth swords illustrated in the first group in Plate 4.2.1) and a number have very pronounced ricassos. All of the early types fall within the later part of what is generally deemed the Middle Bronze Age, and are unlikely greatly to pre-date 1250BC nor to post-date 1150BC. Given the wide variety of types and small numbers of each type they have been treated here as one group.

Wilburton Swords

The Wilburton series of swords are generally considered as the first of the full Late Bronze Age and an indigenous British type, although swords with very similar characteristics form part of the St Brieuc-des-Iffs tradition in North West France. They are characterised by 'the comparatively short curved ricasso, the prominent, generally wide-splayed shoulders and the simple flared hilt terminal' (Colquhoun & Burgess 1988, 40). Colquhoun and Burgess divide the group into seven variants, mainly by shoulder shape and splay. Their variant G bears a greater resemblance to Ewart Park swords than does any of the others, particularly in the shoulder shape (Colquhoun & Burgess 1988, 51-52). Three swords from this variant were examined in the course of this study and, because of their possession of the 'lozenge' shaped shoulder and ricasso configuration (Colquhoun & Burgess 1988, 66), have been grouped with the Ewart Park swords throughout.

Ewart Park Swords

Ewart Park swords are generally accepted as Indigenous British types which 'developed' from the Wilburton tradition. Colquhoun and Burgess, in their regional analysis of the 'development' of Ewart Park type swords, utilised listings of 'early' , 'intermediate' and 'late' features to define a typological (and chronological) sequence based on the numbers of these features exhibited by the swords. The features listed (Colquhoun & Burgess 1988, 65) deal almost entirely with hilt and ricasso morphology, emphasising the relative uniformity of blade morphology within the type.

The 'late' features, on which the definition of step 4 in their division depends, are almost entirely 'borrowed from Gundlingen swords' (Colquhoun & Burgess 1988, 61) and Ewart Park swords with these features are confined to the South East. The features prevalent in their step 3 are defined as being those most commonly found in conjunction with the 'late' features. Thus these features are defined as 'late intermediate' in all regions because, in the South East, they were combined with 'late', imported, characteristics. Similarly the 'early' features are largely defined by features of Wilburton swords, which also are limited in geographical distribution, and the 'early intermediate' features in all regions are identified as such by the frequency of their combination with these 'early' features (Colquhoun & Burgess 1988, 55-67). To some extent this problem is mitigated by the fact that most of the specified 'early' features are also present on swords, including those which have clear affinities with continental types, which pre-date and are more widely distributed than the Wilburton type. Nonetheless, it would appear possible that not only the chronology but even the validity of the sequence itself may be rather more questionable outside the South East.

The Ewart Park swords examined in this study have not been divided into Colquhoun and Burgess' 'developmentally' defined subgroups both because of the regionality of the features used and because the distribution of those features 'is continuous and they (the swords) do not divide into discrete groups' (Colquhoun & Burgess 1988, 61).

Late Swords

The swords classified in this study as Late include two complete or near complete and several fragmentary Carp's Tongue swords. This distinctive type, one of which is illustrated first in the group of Late swords on Plate 4.2.1, has a blade 'with parallel sides narrowing sharply to the 'carp's tongue' point' and a 'wide hilt tang with straight sides which curve gradually into short straight shoulders', which 'overhang a short vertical ricasso' (Burgess and Colquhoun 1988, 108). This type is clearly intrusive and limited to the South East, where, chronologically, it overlaps Ewart Park metalwork, (Burgess and Colquhoun 1988, 110-111). However, the dating of continental Carp's Tongue swords implies that they coincide with the later Ewart Park types. The bulk of the Late category in this study comprises those swords with 'Gundlingen' type features, particularly the 'long narrow leaf shaped blade' with 'rounded centre section' extending 'in a spiked tongue' onto the tang, which is characteristically wide with very wide splayed shoulders (Burgess and Colquhoun 1988, 114-115). The last two swords shown in Plate 4.2.1 are of this type. The debate about the origins of these late characteristics, whether 'British' or 'Continental' , remains open and has recently been reconsidered in considerable detail (Coombs in prep.). The currency of such features in Hallstatt C swords does place them late in any sequence in Britain, whether imported or otherwise.

1.2.2 Spearhead Typology

Bronze spearheads, unlike swords, were present throughout most of the British Bronze Age, although hafting arrangements changed with time. Spearheads which were attached to shafts by means of tangs were current only during the Early Bronze Age. All other spearheads had hollow sockets into which the top of the shaft fitted but the means of securing the spearhead to the shaft varied and again the variation seems to have had some chronological significance. Spearheads with loops on the sides of the socket, either at the open end or the middle of the socket are generally accepted, largely as a result of their frequent association with artefacts typical of the period but also, increasingly, as a result of radiocarbon dating of their shaft wood, to have preceded the introduction of swords and these therefore fall outside the scope of this study. Spearheads with attachment loops at the base of the blade and socketed spearheads, which were hafted by means of 'pegs' passing through holes in the sides of the socket and going into, or even through, the shaft, are generally accepted as later and were therefore included in this study.

Most post-war discussions of bronze spearheads have essentially used a descriptive typology (e.g. Burgess *et al.* 1972, Coombs 1975, Ehrenberg 1977) which, given the wide variety of types appearing in any one large weapons hoard, appears the most comprehensible way to define the types. The major exception to this practice within the literature for the period 1250-750BC is the Watford hoard (Coombs 1979), in which a distinctive ogival bladed type of socketed, pegged spearhead constituted a high proportion of the spearheads present (see Plate 4.3.1(a)). Certain types of spearheads may be referred to as of Wilburton, Broadward or Carp's Tongue 'type', after the hoards in which they were first characterised, but these terms cover a variety of different individual types generally found in association with each other and/or with swords of the type in question (Burgess *et al.* 1972, 229).

Any spearhead can be described in terms of its blade shape and five different groups of blade shape were considered for the purposes of this study. These were lanceolate, flame-shaped, ogival, barbed and triangular and are illustrated in Plate 4.3.1(i). Many spearheads have special features, such as blade openings, stepped blades, fillets and channels, hollow cast blades, etc., as illustrated in Plates 4.3.1(ii)-(x), which enable them to be grouped together, although the largest group consists of those with plain lanceolate blades.

All of the spearhead characteristics analysed in this study are defined in detail and their significance in terms of the design and use of the weapons are considered in Chapter 4 below. The chronological significance of spearhead typology has been increased considerably by the recent radiocarbon dating of wood from spearhead shafts, some results of which are shown and discussed below, and the availability of further dates from a wide spread of geographic regions in the future is likely to increase it yet further. Indeed it is to be hoped that the presence of spearheads with certain characteristics may eventually provide a finer chronology, particularly for weapon hoards, than is currently available, and that sword typology need no longer be given precedence. However, the prevalence of the plain lanceolate spearhead throughout the Late Bronze Age is likely still to mean that, in a great many cases, spearheads with the required distinguishing features will not be found and that sword typology will, in these instances, continue to provide the best chronological marker.

The radiocarbon dates for examples of various types of spearheads from a recent radiocarbon programme are listed below (Needham 1997, Tables 1 and 4):

Type	Laboratory Reference OxA-	Radiocarbon Measurement BP	Calibrated Range BC (95% probability) from	to
Basal-looped Blades:				
lanceolate & channeled	5949	3110+/-50	1520	1260
lanceolate & channeled	6177	3055+/-50	1440	1160
lanceolate	5196	3035+/-40	1420	1210
triangular	5187	3045+/-55	1440	1130
triangular	5953	3015+/-45	1410	1120
triangular & channeled	5952	2965+/-45	1320	1040
'Tear'-shaped Blade:	5954	3025+/-55	1420	1100
Pegged Lanceolate Blades:				
plain	5036	2920+/-50	1310	990
lunate openings	5955	2900+/-45	1260	980
hollow cast	5035	2900+/-45	1260	980
fillet defined	5034	2890+/-45	1260	930
fillet def., straight based	5056	2850+/-50	1220	900
decorated	5186	2840+/-40	1160	900
multiple stepped	5184	2830+/-65	1220	840
multiple stepped	5185	2770+/-50	1040	820
straight based	4506	2825+/-50	1160	840
fillet defined	4655	2760+/-50	1020	810
plain	5188	2780+/-35	1010	840
Ogival (Watford type) Blades:				
decorated	5957	2810+/-45	1100	840
plain	5962	2685+/-60	900	790

These show clearly the relatively early place of the basal-looped spears, particularly those with lanceolate blades and channeled lanceolate blades. The triangular bladed and channeled triangular bladed basal-looped examples seem contemporary with the 'tear' shaped blade, which, despite having no openings in the blade, is very similar to the small group of 'protected opening' blades. However, although the date ranges do show that the 'Wilburton' type spearheads, such as the lanceolate hollow cast, lunate-opening and fillet-defined midrib blades, generally pre-date the multiple stepped blades of the Blackmoor hoard and, in turn, the relatively late ogival, Watford type, spearheads, they demonstrate the potential for overlap as well as the longevity of the basic lanceolate plain blade.

1.2.3 Chronology

The dating used for British bronzes has always owed much to analogy with those few artefacts from securely dated British contexts and those typologically similar artefacts found in continental Europe, whose dates are also known. Where no such well dated analogues exist assumptions were generally made as to the speed of typological 'progression', between one well dated type and another. The manner in which the dating system was put together, with little coherence between metal 'phases', site dating and pottery types, or indeed between different geographical areas within the British Isles, left something to be desired.

Fortunately, during the course of this research, a comprehensive revision, incorporating both the results of a recent programme of radiocarbon dating of organic material, such as spear shafts, unequivocally associated with the metal artefacts (Needham et al. 1998), and of revised, and more accurate, dating of many Bronze Age sites, has been put forward. Needham (1997) has now divided the Bronze Age into seven periods, taking into account metalwork assemblages, pottery styles, sites and radiocarbon and dendrochronological dating. His system, as illustrated in Figure 1.2, has been designed to preserve broadly the usual divisions into Early, Middle and Late Bronze Age but the date attributed to the start of the Late Bronze Age has been moved back to circa 1150BC, from the previously widely accepted 1000BC, and the Early Iron Age has been deemed to start around 750BC and to include the type of mixed iron and bronze metalwork assemblages, of the type known as 'Llyn Fawr', previously often assigned to the Late Bronze Age.

This system of division is not only much clearer than previous proposals but has the advantage of incorporating all known factors within one framework. There remains a possible problem in equating dates and artefact typologies over the whole island, since 'regional inconsistencies within Britain .. will perhaps eventually overstretch the tolerance of an all-embracing periodisation and thus demand the creation of geographically more restricted frameworks' (Needham 1997, 4). This remark may be particularly appropriate to the swords of the Late Bronze Age given that the Period 6 swords (Wilburton type) are restricted to the South and East of the country and there appears to be no Northern equivalent since the re-assignment of Wallington type metalwork to the preceding period (Needham 1990b), leaving open the possibility that the Period 6 'package' in the North may have included Ewart Park type swords which are a part of the Period 7 'package' in the South and East. Despite this caveat*, which will be further discussed with the results of this programme of research, this revised dating framework has been used throughout.

Needham's Late Bronze Age Periods 6 & 7 (1150-950BC & 950-750BC) cover the vast majority of the material considered here but it was during Needham's Period 5 that swords were first adopted in Great Britain and, for the purposes of what follows, the last century of this phase (circa 1250-1150BC), which saw the inception of Post Deverel Rimbury (PDR) pottery styles, will also be referred to as 'Late Bronze Age'.

In all that follows the use of BC denotes either calendar dates or calibrated radiocarbon dates, while uncalibrated radiocarbon dates are denoted BP (before present). In all cases, except dendrochronological dates, the use of a single date implies that it is the central date of a distribution of dates within which the calendar date is likely to fall.

* *Radiocarbon dates, obtained since initial submission of this thesis, are discussed in Chapter 7.*

1.3 Literature Review

The literature on the British Late Bronze Age was originally largely confined to artefact analyses, in particular of the metal objects, based firmly on the empirical approach of the early antiquarians and the categorisations of collectors (e.g. Evans 1881). During the course of this century these have developed into increasingly sophisticated typological studies, many of which, as discussed in Chapter 1.2 above, were primarily aimed at chronological definition. The works which relate directly to the artefactual and metallurgical analyses of this study are discussed in Chapter 1.4 and 1.5. Those which have provided the context for these studies are outlined below.

During the last thirty years there has been immense interest in environmental studies which have utilised the panoply of palaeoenvironmental analysis techniques to try to reconstruct the climate and agricultural economy of the period. Throughout the same period there has been substantial progress in the undertaking and publication of landscape surveys (e.g. Fleming 1988) which have contributed greatly to the understanding of prehistoric land use and have also assisted in the identification of sites, some of which have very little obvious structural content. In addition the greater requirements laid upon contractors to assess the archaeological 'value' of the areas they were about to 'develop' led to an explosion of activity in rescue archaeology, particularly during the property boom of the 1980's, which unearthed sites of many periods. Methods of excavation and retrieval techniques have improved vastly over the years and, as a result, reports of site excavations have become very detailed and the identification, even in multiphase sites, of the most ephemeral traces, such as those of the Late Bronze Age often are, has increased dramatically.

Much of the initial analysis of the results of these landscape, site and environmental studies was framed with a bias towards socio-economic methods of interpretation, such as those used to formulate 'modern' computer based social and economic forecasting models. This approach followed the processual school of the 'new archaeology' in rejection of empiricism and in the belief that general models, applicable to different contexts, could be developed and that archaeological theories could be 'scientifically' tested (e.g. Binford 1966, Binford 1978). The (structural) Marxist school of analysis tended to invoke concepts of socio-economic power relations as an interpretive tool (e.g. Rowlands 1976, Kristiansen 1978) but continued to 'test' hypotheses. Naturally many of the artefact analyses, particularly those concerned with metal composition, production, manufacture and use of artefacts, especially during the 1970's, were conducted with a similar mindset, reinforced by the use of terms such as 'industry' and 'trade' whose twentieth century meanings, redolent of Henry Ford, seem far removed from any hint which remains of the likely reality of life in the Late Bronze Age.

The development of post-processual schools of thought in Britain has sought to produce interpretations rooted within their social context (Hodder 1986, 1989) and this has strongly influenced the reinterpretation of existing data and the study of new evidence in recent years. Although the constraints of dealing with the nature of society via limited, if detailed, evidence on a very local scale mean that there may even be some temptation to over-interpret evidence which is of dubious significance, definite conclusions are less frequently drawn than heretofore, which reflects both an acceptance of the uncertain and incomplete nature of the evidence as well as the philosophical approach of the authors.

Although it is essential to interpret the remnants of material culture within its social context, the interpretation is also invariably made within the interpreter's own social context and the existence of a range of alternative interpretations, then and now, has to be acknowledged, even if this deprives the reader (and the interpreter) of the crutch of certainty. This was more elegantly put as: 'An interpretive archaeology tries to get close to understanding how other ways of seeing the world were once - and one hopes, still remain - possible; nothing more' (Barrett 1994: 171). The extent of the range of interpretations may be limited by a lack of imagination on the part of the author but may also, more prosaically, be limited by incompatibility with the available material evidence.

1.3.1 War

The philosophical or political approach adopted can lead to self-imposed limits on the scope of inquiry, in much the same way as the quasi-scientific straitjacket of the early processual school did. A major victim within academic archaeology of both these schools of thought has been the study of war as an intrinsic part of the organisation of prehistoric society. The early empiricists and, to some extent, their continental successors had no such inhibitions. Some, indeed, might even be accused of overemphasising invasion and armed conflict in archaeological interpretations (e.g. Gimbutas 1965). Archaeologists of historic periods (e.g. Oakeshott 1960) have either been happy to study the subject or have at least been unable to ignore the part played by warfare. Even in this context its study has been limited in recent years and preferences for the study of more peaceful aspects of life have been evident.

Prehistorians have mentioned warfare, in general texts, as an explanation for obvious archaeological remains (Sharples 1991: 79), such as the weapons and hillforts of pre-Roman Britain, but even a work such as 'The Passage of Arms' (Bradley 1990) is in fact a study of hoarding and votive deposition - undoubtedly important factors in the prehistoric role of arms but surely not the only ones. There was an attempt to rejuvenate the study of the role of prehistoric warfare via a conference, organised by the Prehistoric Society in Oxford in 1989. A more recent conference, 'Ancient Warfare: Archaeological Perspectives' at the University of Durham in 1996, whose proceedings are to be published, addressed the subject from the points of view of anthropologists, prehistorians, classical, near Eastern and medieval archaeologists, and included some fresh insights.

Anthroplogists have, seemingly, been undeterred by the 'unmentionable' nature of the subject, as epitomised by a rather blunt approach to the analysis of 'primitive war' (Turney-High 1949), although there was some hint of an hiatus in studies in the late 1950's and 1960's. There has since then been a steady stream of articles and books on the subject, including some substantial volumes on the anthropology of warfare, using examples from both historical and current studies. Some of these have tended to treat war as a separate and universal phenomenon for which general explanations exist, as did the volume written largely from a materialist/ecological perspective (Ferguson 1984), and such 'ecological' explanations have had their reflection in discussions of Late Bronze Age phenomena in Britain (e.g. Burgess 1985). Others were based on seminars held in the U.S.A. in 1986 (Haas 1990), which embraced most major approaches to the subject, and 1989 (Ferguson and Whitehead 1992), the latter dealing specifically with the effects of contact with expanding states on indigenous patterns of warfare.

The main reason, one suspects, for this difference in attitude is that during the study of living peoples, it is difficult to ignore the fact that violent conflict is usually regarded as a more or less 'normal' aspect of their existence. Indeed, it is highly probable that my own Ulster upbringing within a culture which, with considerable justification, sees itself as under threat of ultimate annihilation, as the result of a prolonged campaign of violence, has not only rendered me unable to ignore the interweaving of war with culture, religion, history, social structure and economics but has drawn me actively to pursue its study.

1.3.2 Death

Studies of the British Late Bronze Age have been hampered by the almost total lack of funerary remains which, for studies of the preceding two millennia, have provided fruitful ground for the formulation of theories of social groupings and hierarchies. The actual human remains found have recently been surveyed from the literature and the potential for interpretations of their treatment as metaphors for social concerns has been discussed (Bruck 1995). Nonetheless it is striking how few and how fragmentary these remains are. They provide no evidence for the funerary practices of the period, if any did indeed exist, and are equally unhelpful as evidence of violence, far less of warfare. What this lack of physical remains clearly demonstrates is how far funerary practices had, by the Late Bronze Age, departed from those which produced the burial mounds of the Early Bronze Age and the intervening 'Deverel Rimbury' Middle Bronze Age cremation cemeteries. That the change is significant seems incontrovertible and that its basis lay in cultural change seems reasonable - the extent, the reason for and the manner of that change are less than clear.

1.3.3 Sites

The site record for the period was also, at one stage, sparse in the extreme but recent improvements in radiocarbon dating techniques combined with a number of lengthy and, in some cases, well documented excavations have served to identify a respectable number of sites. The state of play in the recognition of Late Bronze Age sites and the then current thinking as to their functions and chronologies were discussed in a paper originally given in 1986 at a conference in France (Burgess 1988). Since then new sites with potential later Bronze Age phases have been discovered, such as the 'causeways' at Testwood Lakes in Hampshire (Fitzpatrick *et al.* 1996) and at Shinewater, East Sussex (Denison 1997). Others have now been dated and published; e.g. Flag Fen (Pryor 1991, Pryor *et al.* 1992), with its enormous wooden platform, post alignments and ritual depositions, and Beeston Castle in Cheshire (Ellis 1993), whose multiphase defenses started in the Late Bronze Age. Even more sites are as yet far from fully analysed or published (e.g. Springfield Lyons in Essex and Thwing in Yorkshire). The sites most relevant to the subject of this study are those which may have been used for 'military' purposes, defensive or otherwise:

'Fortified' Sites

Some of the more recent evidence is incorporated in a study of settlement and ritual in South-East Britain, wherein particular attention is paid to the 'ring-forts' of the period (Needham 1992). Contemporary with the Bronze Age hillforts, these 'defended' sites, which do not have the obvious advantage of a hilltop setting and often exhibit a rather large number of entrances when compared with an ideal military fort, seem to have few settlement and a number of ritual characteristics. However, there are also signs of military connotations at some of these sites in, for example, the presence of sword mould deposits at Springfield Lyons in Essex.

The interpretation of hillforts as essentially practical in purpose and defensive in nature has, by contrast, rarely been questioned. Aspects of hillforts of Wales and the Welsh Marches were discussed in papers (Hogg 1972, Stanford 1972) published in the edited volume of essays in honour of Lily F. Chitty (Lynch & Burgess 1972). Writing within the then prevailing view of hillforts as a phenomenon of the Iron Age and later periods, Hogg analysed the size-distribution and avoided any conclusions as to dating. In what he described as 'rather elementary generalisations', he equated small forts with defended single family farmsteads, or, in the better defended cases, 'castles', introduced by 'landings' along the coast. He saw the larger hillforts, further East, as defended 'villages or towns' in areas capable of supporting greater population density, while similar sized sites, of a different nature, in the West were interpreted as the defences of the original inhabitants against the invaders. Stanford wrote on the function and population of the larger hillforts in the Central Marches and produced 'population estimates' for the Iron Age in the area based on some rather dubious assumptions, such as that no settlement existed outside hillforts, and tenuous extrapolations from the evidence for dwellings on one excavated site.

The approaches used when the study of hillforts in general was updated in an edited volume (Harding 1976) were, in some cases, rather more sophisticated, although many papers were simply descriptive accounts of excavations. The volume included a reappraisal of the Welsh hillforts (Savory 1976) taking into account the Late Bronze Age radiocarbon dates derived from the hillforts at the Breiddin (Musson 1976) and Dinorben (Savory 1970 but see also Guilbert 1980) and the existence of settlement activity at a number of sites outside the area, e.g. Mam Tor (Coombs 1976), which later became hillforts. The opening chapter in the volume also acknowledges the appearance of some Late Bronze Age dates (Avery 1976, 35) for hillforts and includes a figure giving the calibrated ranges derived from dates available in 1973.

Avery's subsequent analysis of the Southern hillforts (Avery 1993) is most comprehensive for the area concerned but his, reluctantly reached, conclusions concerning their dating, that is that few if any pre-date 800BC (Avery 1993, 152), now seem a little conservative, in the light of recent radiocarbon results. Radiocarbon dates, using extracted collagen from bones, have confirmed the presence of defences of the Middle/Late Bronze Age transition at Rams Hill (Bradley and Ellison 1975, Needham and Ambers 1994) and the Breiddin, Powys and the first rampart at Beeston Castle are securely dated to the full Late Bronze Age (Needham and Ambers 1994, 240). There is, admittedly, still only a small number of hillforts with actual defenses proven to be in existence by the early first millennium BC, the majority of which are in the West, but there is no doubt that a considerable number of such defensible sites were in use during the Late Bronze Age, although the question of their actual fortification or, indeed, their use for defensive purposes is arguable.

Avery has, with considerable effort, been able to 'reconstruct', from the literature and site visits, the designs and techniques used for hillfort construction and has analysed in some detail the practical application of defenses and the tactics of attack which they were designed to withstand. He epitomises the earliest types of hillfort fortifications, his 'wall and fill' varieties, as being 'highly effective against hand-to-hand warfare with spear and sword' (Avery 1993, 36) and places his 'dump' ramparts as later, with the low ones designed also to withstand attack by fire and the high to counter missile attack, with entrances designed to facilitate missile defense (Avery 1993, 64). This distinction fits rather nicely with use of what appears to have been the standard Late Bronze Age weapons of spear and sword and, especially, the rather puzzling lack of evidence for the use of arrows.

1.3.4 Mining

The hillforts dated to the Late Bronze Age are generally situated in areas near to potential or actual sources of metal, particularly copper, especially in Northern and Eastern Wales and the Welsh Marches. They also could be construed as providing a barrier between these areas and the rest of the country given the difficult terrain and limited supply of navigable waterways.

Bronze Age exploitation of early mining sites has been recognised by means of the characteristic stone mauls, which are or have, in historic times, been found nearby. Other sites, located during eighteenth and nineteenth century mining operations, were often attributed to Roman mining. A number of these, including the Great Orme, proved, on re-exploration to be more ancient in origin. Within the last ten years a number of mining sites in Wales and the Marches have been identified as having been exploited during the Bronze Age. A number of these have produced artefacts and/or charcoal which have been dated to the Early and Middle Bronze Age (from approx 2000-1300BC). A number of the radiocarbon dates span ranges including the start of the period here considered but only the Great Orme at Llandudno has produced dates showing exploitation into the Early Iron Age (Craddock 1994:71).

Much of the early work on these sites has been published (Crew & Crew 1990). At the University of Sheffield's Archaeometallurgy Workshop in May 1995 (hereafter SUAW 1995) and the conference, 'The Prehistory of Mining and Metallurgy', run jointly by the British Museum Department of Scientific Research and the Early Mines Research Group in September 1995 (hereafter BM/EMRG 1995) the amount and quality of the research now ongoing was made clear, although only some of the papers given have since been published.

Recent excavations, such as those undertaken by Simon Timberlake and the Early Mines Research Group at Parys Mountain, Anglesey, Nantyreira, on the slopes of Plynlimon, and Copa Hill, Cymystwyth, have turned up emphatic and datable evidence of Bronze Age exploitation, including a hollowed log drainage launder and bone and antler tools (Timberlake 1989(a), 1989(b), Craddock 1994). The mining site at Alderley Edge has been dated to the Bronze Age using a wooden shovel found in the last century but only recently recognised from the literature and traced from its original post excavation 'preservation site' under a school stage (Garner *et al.* 1994). The rapid escalation in the number of sites now firmly dated to the Bronze Age and the extent to which a number of these have been investigated has been remarkable, given the immense difficulties in finding and excavating sites in such remote and inhospitable locations.

In many cases the Bronze Age exploitation, although extensive, is, by modern industrial standards, relatively modest and the evidence is frequently masked by the debris of recent mining. Furthermore no site has, as yet, been identified as a Bronze Age smelting site. There can be no doubt that smelting did take place but the processes used in ancient times may have left only ephemeral traces and, indeed, it is possible that some did not produce much, or even any, slag (Craddock 1989). It is also possible that any traces left may have been comprehensively buried under modern mining debris (Craddock - pers. comm.) or, as was the case with some Early Christian period furnaces at Ross Island in South West Ireland, were located at some distance from the mine and merely covered over by a relatively thin layer of soil or peat (O'Brien SUAW 1995, BM/EMRG 1995).

The application of palaeoecological techniques to potential mining and metal working sites has now been undertaken by Mighall on several British sites, including Copa Hill (Mighall and Chambers 1993) and by Marshall in Austria (Ottaway & Marshall in prep.). The technique combines a detailed analysis of the pollen record showing changes over time in the local flora, a study of the record of heavy metal concentrations and radiocarbon dating to provide an insight into the periods of metal exploitation on both excavated and, more valuably, on unexcavated sites. Such methods have the potential to identify not only mining but also smelting sites and provide a dated sequence of their use. A core taken from Llanymynech has already been subjected to pollen and heavy metals analyses (Moore 1991). Several papers at recent conferences (e.g. Timberlake BM/EMRG 1995) have alluded to this site as one which could well date back to the Bronze Age but it remains to date the core to settle the issue.

1.3.5 Movement of materials and artefacts

That movement of materials was necessary in the Bronze Age is clear from the limited availability of copper and, especially, tin ores. Some raw materials, such as certain stones used in axe making (Cummins 1974), obsidians (Renfrew *et al.* 1968) and clays used in pottery (Peacock 1969), may be traced to their original sources using a variety of analytical techniques. Thereby 'local' and 'exotic' products can be identified even in morphologically similar artefacts. However, in recent years the limitations of such analyses have become increasingly obvious both in the scope of the materials capable of being uniquely identified with a source and in the power of the models used to infer the 'processes' which led to the observed artefact distributions (Bradley & Edmonds 1993, 7-9).

The peaceful exchange of goods is such a fundamental aspect of historical and modern life that it has been invoked by almost all archaeologists as a method whereby materials reached areas which had no such natural resources and artefacts originating in one area (as demonstrated by raw materials and/or typology) reached another. Other 'explanations' of course exist and the classification of these requires consideration (Needham 1993a); goods may be seized by raiding, tribute may be extracted by conquest or threat of violence, invaders who settle may bring their goods with them, tribute may be 'freely given' as a result of perceived social or religious obligations, the movement of marriage partners from one community into another often involves the movement of goods, both with the person moving into the new community and from the new community to the old (the latter is often viewed as a form of exchange). The possibility that the movement of goods resulted from invasion or conflict tends to have been ignored completely for some considerable time as 'economic' analyses and interpretations have gained full sway. In recent years the growth in 'social' explanations has also been notable.

Several edited volumes have made extensive use of concepts of exchange to assist in the analysis of other factors such as social complexity (Renfrew & Shennan 1982) and power relations (Rowlands *et al.* 1987). More recently the analysis of trade and exchange *per se* has been discussed (Scarre & Healey 1992). The growing appreciation of the obvious fact that 'the archaeological record' is a biased remnant of the deposition practices of prehistoric societies and not an accurate representation or even necessarily an approximation to the material culture of the societies in question (Needham 1993a) necessitates a re-appraisal of the distribution maps on which many studies of exchange have been based.

1.3.6 Deposition

The phenonmenon of hoard deposition has been discussed by a number of writers and the review of the changing theories given by Taylor (1993, 3-22) is comprehensive for Britain and Northern Europe. Various 'economic' categories of 'hoard' have been defined based broadly on interpretations of the hoarder's occupation and dependent on the content of the hoard while 'votive' hoards have been defined more by the type of context in which it was found. There has generally been a distinct preference for 'votive' explanations on the Northern continent, first propounded by Woorsae in Scandinavia, and 'economic' explanations in Britain and Western Europe, as shown by Evans' references to personal, merchant and founder's hoards (Tayor 1993, 3&12), but both types of interpretation have frequently been used simultaneously and the balance of fashion has waxed and waned over the century. Less used in Britain have been explanations based on the (non-ritual) motive of the hoarder which, according to Bradley (1990, 15) predominate in central Europe. More recently 'social' explanations, often based on ethnographic parallels, have been added to the panoply and theories of 'competitive' deposition to gain or maintain prestige or as a substitute for conflict have gained ground (Parker Pearson 1993, 117). As with the analyses of metalwork, the explanations proffered for hoards have often provided a rather more recognisable record of the preoccupations of their authors than of the society which deposited the artefacts.

Although hoards have always been recognised as important and worthy of explanation many single finds have been put down to accidental loss. Even some prestigious items deposited in rivers have sometimes been attributed to such causes as erosion from riverbank settlements - an explanation broadly ruled out by their non fragmentary state (Needham and Burgess 1980) - and accidental losses during transit or conflict from boats or at fords.

Pryor, during the course of his excavations at Fengate and Flag Fen was forced by the accumulated evidence to change his initial interpretation of the Flag Fen complex from that of a 'crannog' settlement to a massive 'liminal' ritual complex wherein almost all deposition is deliberate and votive in nature (Pryor *et al.* 1986, Pryor 1992 and 1998).

Bradley (1990) has recently discussed the subject of intentional hoard and river deposition covering the period from the Neolithic to the Iron Age and has discerned an underlying sequence of change in motive for and content of deposition within a framework of continuity of ritual. He sees the Late Bronze Age as particularly complex in that hoarding motives were 'dual', that is both votive and economic explanations must be used to explain the patterns of hoard deposition. He interprets some of the votive depositions as substitution for or components of funerary traditions and sees the 'economic' hoards as resulting from 'an almost unique crisis in the flow of metals' (Bradley 1990: 195). I infer, from subsequent remarks, that he implies that there was a shortage of metal. This contrasts strongly with a rather different, and earlier, 'economic' explanation which put many Late Bronze Age hoards down to wholesale dumping of surplus supply in the face of collapsing demand as iron 'took over' from bronze (Burgess 1979), an explanation which admirably foreshadowed the onset of 'market economics' in 1980's Britain.

1.4 Artefact Research Review

The publication of The Ancient Bronze Implements, Weapons and Ornaments of Great Britain and Ireland (Evans 1881) can be seen as the foundation on which artefact studies in Britain since then have been built. This, while not an exhaustive listing of the then known bronze artefacts, was fairly comprehensive and dealt with the subject by dividing the artefacts into utilitarian categories and analysing the different morphologies contained within each category. The implicit assumption of gradual technological progress was used to provide an ordinal dating and a further assumption as to the pace of this 'progress' was used to provide a first estimate of calendar dating by working back from the Iron Age (Evans 1881, 471-473). Comparisons of technical and aesthetic aspects were made with material from all over the ancient world but Evans clearly recognised the extent of local variation and rejected a rather arbitrary division of Europe into three 'provinces' (Evans 1881, 477-479), mainly on typological grounds. A chapter in this volume (Evans 1881, 415-454) dealt with the manufacture of the artefacts and the materials used and quite clearly set the agenda for future scientific investigations.

Evans' approach has been followed by many archaeologists and a series of ever more detailed typological analyses has culminated in a set of metalwork characterisations incorporating all contemporary utilitarian categories found in association, named usually for a typical hoard, on which most of the fine chronological subdivisions of the Late Bronze Age still depend. These metalwork stages have continued to be compared typologically with continental artefacts by many (e.g. O'Connor 1980) and hence 'linked' into the continental dating systems. Among the influential exponents of typological classification as applied to the British Late Bronze Age has been Burgess who, with others, produced a number of studies (including Burgess 1968a, Burgess *et al.* 1972) which incorporated, refined and added to previous sets, most notably that put forward by Hawkes in 1960 (Burgess 1968a, 1).

The studies have basically been of three, not mutually exclusive, types; those analysing one category of object (e.g. Cowen 1967, Trump 1962 and Ehrenberg 1977), those looking at 'hoards' of associated objects, either individually (e.g. Colquhoun 1979, Coombs 1979a, 1979b), grouped by category of object contained (e.g. Coombs 1975), or regionally (e.g. Taylor 1993) and those looking at all categories on a regional basis (e.g. Pearce 1983, Coles 1960, Burgess 1968a). A number of studies have either been limited to individual museum collections (e.g. Hawkes and Smith 1955) or have formed the relevant catalogues for those collections (e.g. Savory 1980). A number of analyses of metalwork have been carried out and published as a part of site excavations (e.g.

Needham 1993, Coombs 1992) and it is now common practice to have a specialised report on any metalwork found during excavation within the final publication.

The results of all these studies have been built up piecemeal over the century and, although further corrections and refinements are constantly made, they constitute a set of widely accepted metalwork classifications for the British Late Bronze Age. However, as mentioned above, the chronology derived from them has now been thoroughly revised and incorporated into a more comprehensive system (Needham 1997).

While continuing the tradition of concentrating on typology and chronology, Pearce's description of the development of Bronze Age society in her study of the South Western metal work (Pearce 1983) was also a brave attempt to relate the study to the people who created the objects and, in turn, to make it comprehensible to the interested amateur.

Taking a more socio-economic tack, Taylor applied Kristiansen's (1984) approach to wear analysis to the South Eastern metal hoards, and set the results against a 'core - periphery' model of society and a 'prestige goods' economy (Taylor 1993, 104). He identified 'core' areas as those showing large amounts of hoarded metalwork in any one period and 'peripheral' areas as those which did not and interpreted the evidence as showing fluctuations in status (as core or periphery) for various regions within Southern Britain during the Bronze Age. He failed, in his interpretation, to reach any real conclusions concerning the variations in wear which he discerned. Whether or not the results really support his preferred model, as opposed to any other, is debatable and the identification of hoard deposition with 'core' status appears rather simplistic. Indeed he states in his conclusion 'To consider hoards in isolation proves itself to be misguided ...we have discerned the components, but we have yet to recognise fully the larger system which lay behind it'. Further aspects of his methods will be discussed in Chapter 1.4.2 below since they relate directly to the present study.

1.4.1 LBA Weapons

The study of weapons has generally followed the early approaches outlined above. Indeed the weapons have often been crucial in establishing the typological and chronological framework for the British Late Bronze Age.

It would be difficult to discuss bronze swords without mention of Cowen whose studies included continental European swords and who sought to establish a sequence of development embracing both British and European types (Cowen 1951 and 1967). The magnum opus, 'Swords of Britain', which was dedicated to him, (Colquhoun and Burgess 1988), could be described as a tour de force in the art of the analysis of typological development.

The typological subdivisions of British bronze swords were made therein on both a regional and a chronological basis. There is an implicit assumption of a consistent pattern of 'evolution' over time from one type to the next. The assumption was also made that there was little variation in either the direction of 'progression' or date for the major types across the country. An obvious gap in the sequence, such as the lack of 'classic' Wilburton swords outside the South and East, was attributed to the more 'advanced' nature of that region. The chronological framework used was partly defined by certain characteristics of the swords themselves which leads to a certain element of circularity in the discussion of dating, although this was probably inevitable given the lack of available and reliable dates from undisputed associations.

The recognition of regional differences within major typological divisions and, in particular, of the necessity of using a regional approach to establish any recognisable internal 'progression' within the Ewart Park types (Colquhoun & Burgess 1988, 55) was a considerable advance. However, since no two swords seem to be identical and the variation in minor characteristics is wide, the appropriate grouping within the fine subdivisions produced would not be immediately obvious on viewing a new find. Indeed even differentiation between the major groupings is at times difficult. In particular Burgess' Wilburton 'G' variant, which includes the majority of the few Northern examples of Wilburton swords, has considerable affinity with the Ewart Park tradition and leads to the conclusion that the latter type was developed in the North, though this is seen merely as an example of 'the enduring tendency of the North to simplify fashions received from the South' (Colquhoun & Burgess 1988, 68).

Ehrenberg has discussed and catalogued bronze spearheads from a fairly limited region, basing her classification on 'descriptive terms as used by Burgess, Smith and others' (Ehrenberg 1977, 1). The discussion of classification includes some material from outside the three counties studied and there is a brief discussion of the manufacture and use of the spearheads. A full study and catalogue of British spearheads remains an obvious gap in the literature.

Some have mixed a typological and functional approach to the study of bronze weapons. Brown (1982) has used an analysis of utilitarian aspects of the design of two typologically differentiated sword groups (Wilburton and Ewart Park) to propose a different interpretation of their relative chronology than that currently accepted, arguing that, since there is no obvious utilitarian advantage attached to either type there is no reason for one to have preceded the other. Oakeshott (1960), in his opening chapter, discusses the practical considerations of the use of prehistoric weapons.

Coombs has taken a very different approach to the interpretation of weapon hoards and his emphasis is not on the necessary but routine description and typology but on analysis of 'the social significance of the hoards and their metalwork' (Coombs 1975, 50). He examined the weapon hoards from the entire British Bronze Age and interpreted the increased weapon deposition of the later Bronze Age as appearing 'to reflect a period of unrest caused by an increased pressure on the available land due to population growth and climate decline' (Coombs 1975, 77). This was entirely in keeping with the then widely accepted theory that climate deterioration had a universal and disastrous effect on agricultural resources. As research into the environmental evidence has expanded it has shed considerable doubt both on the universality and the disastrous nature of the climate deterioration and appreciation of the potential for an efficacious social response to such difficulties has grown. Coombs found evidence within the contents of the hoards supporting the existence of ranking within both the warrior groups and society in general. He also saw that the circumstances of hoard deposition 'could give an insight into the ritual or religion of the period' (Coombs 1975, 77). This application of a metalwork study in the analysis of social context, an attempt to ' interpret the lives of people' (Coombs 1975, 77), was very much in advance of its time and it is the approach on which it is proposed that this study should build.

1.4.2 Wear Studies

Savage's (1979a) study of surface markings and damage on the Watford swords formed part of a proposed survey of these characteristics for all bronze swords. Unfortunately the study was never published, thus it is impossible to assess the final results. The degree of detail required by the proposed method is daunting and the approach used requires that the marks noted are due entirely to ancient damage, that this can therefore be differentiated from modern damage and that no ancient damage is masked by the effects of modern damage. This would exclude not only heavily corroded swords but also the majority of swords in museum collections, since these have been subjected to a range of cleaning and conservation techniques which could disguise many ancient surface markings.

Kristiansen (1979) made use of the decorated nature of a great deal of Scandinavian bronzework to assess the wear on the ornamented surface, measured by relative depth of engraving on worn and unworn areas of the same object. The major assumption he made was that the swords and ornaments were quite literally worn on the person of their owners. He based a substantial part of his conclusions concerning periods of economic 'stress' on these wear characteristics which he related directly to the time each object was in daily use. This particular type of analysis is denied to British prehistorians since such engraving is exceptionally rare on these islands. In a later paper Kristiansen (1984) attributes the dramatic re-shaping of some blades, from relatively straight to concave, of what would in Britain be termed rapiers, to constant regrinding during a prolonged period of use. The extent thereof can be assessed on a subjective scale by comparison with a typical 'unused' weapon of the same type. Whether this is in fact the cause for the reshaping is uncertain, a similar effect could be achieved by a deliberate reshaping in one grinding operation, but the assumption is not unreasonable. Such reshaping of blades is generally not seen in the British flange hilted swords of the Late Bronze Age.

Taylor, in his study of the South Eastern hoards, assessed 'wear' characteristics, including physical damage, across a wide range of objects which, if used practically, would have been used in very different ways and with very different frequencies. A sword, a spearhead and an axe of equal age are likely to show very different types and extents of damage. A sword wielded in one very violent melee could be damaged sufficiently to render it beyond repair in the space of a few minutes while an axe used for woodwork could be kept in service for some considerable time, subject to re-sharpening when necessary. This problem is admitted by Taylor (1993, 51) as a flaw and many of his analyses were in fact carried out using only the data derived from his examination of axes, but it remains probable that he has underestimated the extent to which it affected his findings as to the differences he perceived in the levels of wear exhibited by different hoards.

It is vital also to differentiate between various types of damage. The effects of corrosion can, after even a relatively limited period, resemble those of traumatic damage and could also remove all traces of processes such as regrinding. It is frequently far from simple to distinguish between damage caused during exposure of the artefact and pre-depositional damage, especially on artefacts discovered over a century ago. Taylor reports that on average he spent 6 minutes examining and taking notes on each artefact and this seems an inadequate time to establish whether damage or markings are ancient or post-discovery for the less recent finds. Taylor (1993, 45) cites Farley as stating that 'he was able to distinguish marks caused by recent handling from ancient damage' but failed to mention the caveat from the same sentence which, in full, was: 'As the hoard was seen within a day or so of discovery it was an easy matter to distinguish between superficial marks caused by post-discovery handling and ancient damage - a factor not always apparent on finds whose history is less perfectly known.' (Farley 1979a, 140). Even in those rare instances when artefacts can be examined immediately after discovery and damage is deemed to be of ancient origin, pre-depositional damage must be differentiated between 'normal' wear and tear and deliberate destruction - the physical characteristics of each type of damage require careful analysis and, ideally, experimental verification.

Studies in the experimental use of bronze artefacts owe much to the work of Coles who even managed to use actual, if unprovenanced, prehistoric bronze swords in his demonstration of the lack of efficacy of the thin sheet bronze shields of the period (Coles 1962). However the availability of such artefacts is limited and the necessity to manufacture replicas before such experimental use means that only small scale experiments are really feasible.

In a recent study of experimental and ancient wear traces on early flanged axes Kienlin showed that there are perceptible morphological differences between the traces of manufacture and those of use in axes used (often to destruction) for wood working and that use wear patterns resembling those produced experimentally by constant repetition of the same simple activity could be recognised by microscopic examination of casts of the surfaces of some ancient artefacts (Kienlin and Ottaway, 1998).

This study will use the comprehensively recorded results of repeatable experiments to assist in the analysis of the evidence provided by the artefacts. Examination of the artefacts will be undertaken with full cognizance of the visible and microstructural effects of manufacturing methods, combat and other pre-depositional damage and, most importantly, post depositional and conservation processes.

1.5 Metallurgical Studies

The history of metallurgical studies of non-ferrous artefacts in British archaeology is long, as is evident from Evans (1881), who not only included a table of compositional analyses (Evans 1881, 421) but also a rejection of previous analyses, made in 1796, as 'only approximative' (Evans 1881, 417), thereby setting a much followed precedent.

The chemical composition of alloys has always been of interest and, with improvements in scientific techniques resulting in the ability to capture ever more detailed and accurate information from ever smaller quantities of metal, has been quite extensively investigated over the years (despite the high cost of the increasingly sophisticated equipment required).

Early methods include simple microscopic visual examination of metallographic samples which can identify and give an approximate guide to the proportions of the major alloy constituents, and other methods, such as wet chemical analyses, which can give more accurate identification and quantitative information. The technique of spectroscopy was based on Fraunhofer's observation of dark lines in the spectrum of sunlight early in the 19th century (Moore 1963, 470). The technique was developed through the century but explanations of the underlying processes had to await the twentieth century when Bjerrum applied quantum theory to the absorption spectra of molecules and Bohr developed his orbital transition theory, based on Rutherford's model of the atom (Moore 1963, 471). The application of wave theory to this model (by de Broglie and Schrodinger among others) was required before the spectra of elements above hydrogen could be explained, although precise solutions remained elusive (Moore 1963, 497)

In the second half of the twentieth century a new range of techniques came into regular use in chemical analysis and hence in archaeometallurgy. These methods all utilise the fact that sub-atomic particles take up energy levels separated by specific constant quanta of energy, which are characteristic of the element concerned and that the intensity of output (or absorption) is directly dependent on the proportion of the element in the material analysed (Vogel 1978, 693-699, 810-814). The range of methods now available is substantial. Among the most commonly used are atomic absorption spectrometry (AAS), X-ray fluorescence spectrometry (XRF), optical emission spectrometry (OES), mass spectrometry (MS), neutron activation analysis (NAA), photon activation analysis (PAA), particle-induced X-ray emission (PIXE) and electron probe micro-analysis (EPMA). Some of these may use different ways of measuring the output, e.g. energy dispersive spectrometry (EDS) and wavelength dispersive spectrometry

(WDS) and some methods have a number of variants, e.g. spark sourced mass spectrometry (SSMS) and induction coupled mass spectrometry (ICP-MS).

There have been a number of studies comparing the results achieved on archaeological and standard specimens using different methods and laboratories. These include those by Chase (1972), Pernicka (1986) and Northover (1996). The studies highlight the extent of discrepancies arising from differing laboratory procedures, reporting styles (Chase 1972) and probable human error (Northover 1996, 359-60). However it does appear that many of the differences which arise are largely systematic in nature (Northover 1996, 359) and can therefore be corrected for when comparing data from different methods and laboratories, albeit that this must be done with caution (Chase 1972, 11).

A more difficult problem in analysis of metal from archaeological artefacts is the heterogeneous nature of the material, on both the macro and microscopic scales (Pernicka 1986, 24). In particular those elements with low solubility in the main matrix constituent which tend to segregate, such as bismuth and lead in copper (Slater and Charles 1970, Rohl 1995, 156)), can give rise to misleading results for the artefact as a whole, especially when sampling a very small area or taking only a few readings from points of a larger sample.

The adoption of Optical Emission Spectrometry (OES) by Junghans *et al.* in the Stuttgart programme (SAM) was the first major attempt systematically to classify artefacts by quantification of their compositional groups and has been subject to a long series of criticisms both of method and interpretation (e.g. Slater & Charles 1970, Tylecote 1970, Waterbolk & Butler 1965).

An early series of analyses of British and Irish copper and bronze artefacts of the Beaker and Early Bronze Age periods (Coghlan & Case 1957) served to identify, by their trace elements, three metal groups. One was deemed to be 'typically a product of Irish mining and metallurgy', another was, due to its high nickel content, deemed to be of 'Central European origin' and the third was thought to be a 'residue' of the other two. The interpretation of the Beaker and metal evidence as showing the presence of metal-working 'immigrants' is open to question, as are the actual sources of the copper but the grouping is fairly clear.

Britton (1961) analysed Early Bronze Age 'Wessex' artefacts in a similar fashion and applied the SAM metal categories to these and to the earlier analyses of Coghlan & Case (1957). He concluded that the use of arsenical and low tin versus higher tin bronzes and the division according to trace elements coincide with Apsimon's typological 'Wessex I' /'Wessex II' division, although no identification of copper sources could be made. In a subsequent paper (Britton 1963), he discussed Late Neolithic and Early Bronze Age artefacts in terms of their typology, technology and associations, using his compositional analyses only to discuss alloying practices.

OES was used by Brown & Blin-Stoyle (1959) to examine a number of objects from the British Bronze Age. This study, unlike previous studies, concentrated on artefacts from the Middle and Late Bronze Age, when, it is generally agreed, recycling of bronze was commonplace. The results of the compositional analyses supported the typological groupings in that the vast majority of Late Bronze Age types examined proved to have lead contents in excess of 1% while the Middle Bronze Age types showed only trace amounts of lead. There were also some differences in trace element concentrations between the high and low lead groups. Further analysis of the results showed some distinction in trace element concentrations within the high lead group, which was interpreted as showing a distinct 'Carp's Tongue' bronze grouping with consistently low values of most major trace elements. The analyses covered a wide range of artefacts but the provenances were mainly restricted to the South and East of England.

Northover (1980) summarised his compositional analyses of Welsh bronze artefacts by defining a series of metal groups based on trace element analyses of the typologically defined chronological groups covering the entire Bronze Age and discussing changes in alloying practices throughout the period. The preliminary results of a similar exercise on bronze artefacts of South West Britain were outlined by Pearce (1983: 105-107).

Northover (1982b) analysed the typologically defined 'Wilburton' metalwork, most of which also comes from the South and East of England, and considered almost 400 compositional analyses, including 149 from the Isleham hoard. He used a few analyses performed by methods other than EPMA and some analyses of French material typologically similar to the British Wilburton material. The survey studied 'the development of leaded bronze alloys and associated casting techniques', 'metal resources employed' and 'the organisation and relationships of the industry' (Northover 1982b, 69).

Northover identifies, by their impurity patterns, two distinct metal groups within the Wilburton tradition and relates these to the typologically derived 'development' within the Wilburton tradition from the preceding Penard metalwork phase to the succeeding Ewart Park phase. Differences in alloying constituents are examined and correlated with the trace element groups. The technology of bronze working during the period is discussed in the context of the massive Isleham hoard, interpreted as a a foundry 'storage pit'. Indications that there are changes in patterns of metal sourcing and recycling during the period are discussed. These are covered in more detail within another paper centred on the British Isles but utilising the trace element patterns detected in the available analyses of European bronzes from all phases of the Bronze Age (Northover 1982a). Northover (1988) drew together the then available compositional analyses, 174 in total using a variety of methods, of 144 British swords and discussed the changes in alloying practice and trace element distribution in relation to the typological 'development' set out by Colquhoun and Burgess (1988).

Rohl (1995) has used lead isotope analysis, a technique which enables lead from different sources to be identified as such by the ratios of its isotopes, in a 'pilot study into the lead isotope character of ores from Britain' with the aim of using such a database 'to compare the lead isotope signatures of Bronze Age artefacts from Britain' (Rohl 1995, 2). Although numerous such studies have been made in other areas, most notably the Aegean (Gale & Stos Gale 1982, 1992a), only one other small study, of 24 Wilburton objects, had previously been carried out on British artefacts, by Northover and Gale in 1982 (Rohl 1995, 2. Northover 1982b, 92).

The technique can be used to establish the lead isotope signature of copper and bronze objects without lead in the alloy since lead is generally present as a trace element in copper sources and such signatures have been identified with particular sources (Gale & Stos Gale 1982). Such a 'unique' identification of copper source does not appear possible for British copper ores (Rohl 1995,176) but the signatures of certain typologically and geographically defined groups of Early and Middle Bronze Age artefacts can be differentiated one from another.

The combination of trace element, lead isotope and typological analyses showed that the Early and Middle Bronze Age artefacts do largely fall into quite distinct groups, even though the origins of the copper cannot be identified uniquely (Rohl 1995). The addition of lead to the alloy in the vast majority of Late Bronze Age artefacts means that only the source of the added lead could realistically be a candidate for identification using this method. The 'Wilburton phase leaded bronzes form such a tight lead isotope group' that Rohl sees 'some prospect, in theory, of isolating the sources of lead in Britain' with the Mendip deposits as 'a feasible source of lead in the Wilburton phase' (Rohl 1995, 154-5). 'The lead isotope results of all the (Ewart Park) objects analysed generally fall into a single extended cluster' which 'appears to overlap with the Wilburton phase lead isotope data' (Rohl 1995, 156). Although 'the range of locations that exhibit leaded bronzes with similar lead isotope compositions is surprising ... the extended cluster of leaded bronze lead isotope compositions happens to agree with the most common range of lead isotope ratios of ores in England and Wales' and 'the Mendips/Bristol area, the Southern Pennines or Alderley Edge are the more feasible lead sources' (Rohl 1995, 159).

Few of the analytical methods used, with the notable exception of EPMA, are capable of being performed on solid samples. Most sampling of artefacts has been done by drilling, which causes relatively little visible damage to the artefacts and, given the increasingly small amount of metal required as the techniques have improved, this seems likely to remain the case. However drillings cannot be analysed metallographically and thus a valuable source of information has been ignored in many of the studies undertaken.

Metallographic studies have, in the past, largely been made on large samples taken from a few, often broken or poorly provenanced, artefacts. Since the early exponents of the use of the technique in archaeology were trained in modern metallurgical methods, where large samples are taken as a matter of course to maximise the information yielded, the sampling was often excessively destructive of the artefacts and there was consequential reluctance to authorise further sampling programmes. The few systematic metallographic surveys which have been done were either surveying the collections of a particular museum (e.g. Allen *et al.* 1970, Coghlan 1970a) or examining the contents of a particular hoard (e.g. Tylecote 1983, Coghlan 1970b). Although such surveys have given a fairly comprehensive picture of the technology and the alloys used in Bronze Age metalwork production, they are largely qualitative in nature and the relative lack of photographic material combined with the extreme brevity of some metallographic reports (especially Allen *et al.* 1970) means that they are much less useful than they could have been. Fortunately some of the samples, especially those taken by Tylecote, Coghlan and Northover are still available for further study.

In addition to the discussion of manufacturing technology evidenced in the Isleham hoard (Northover 1982b), Northover (1988) discusses the methods used to manufacture swords in the British Bronze Age. This draws not only on the evidence provided by the physical residues of the manufacturing process (moulds, tools, etc), a source also used by Needham (1980, 1991b), Coghlan (1975) and Tylecote (1976, 1987) in reconstructing casting processes, but also on the metallographic examinations of some solid samples used for EPMA. Indeed, although few of the metallographic reports have themselves been published, many of the technological points in Northover's work are derived from such examinations.

In the analysis of the Petters hoard, Needham (1990) combines typological analysis with scientific analyses of the technology to propose some explanations of the different contents of the two groups and to clarify the pre-depositional history of the hoard in question. This study used techniques of compositional analysis, trace element analysis, metallography and visual examination of the traces left by manufacturing, on bronzes found in closed context during excavation of a site close to the Thames which is now considered to be contemporary with and, probably, a part of the Runnymede complex (Needham 1992, 57).

This practice of combining the physical evidence with microstructural analysis was also used in a few earlier general studies of manufacturing techniques contained in the archaeometallurgical literature (e.g. Coghlan 1975). In many instances information from archaeological sources has been augmented by the use of experimental results (e.g. Voce 1975, Northover & Staniaszek 1982) where the methods attributed to ancient metal workers have been tested on alloys of similar composition. The results obtained from experiments in casting and working the alloys are, therefore available for comparison with the physical and microstructural archaeological evidence in order to reconstruct how the technology was exploited in prehistory.

The concentration, within metallurgical studies, upon the composition of Bronze Age artefacts has been marked and this largely reflects the desire of the researchers to identify the ultimate sources of the ores from which the metal was smelted. The relative failure of trace element studies, especially when viewed alone, in pinpointing sources in Europe does not seem to have stemmed the flow of compositional analyses, nor the desire to identify sources. Although the information obtained can, as shown by Northover (1980, 1982a) and Rohl (1995), be used to help establish relationships and differences between groups of artefacts, often identified typologically, this aspect of compositional analysis has not received the attention, or funding, which the 'sourcing' studies have attracted. However, the fact that the information can be so used indicates that, wherever possible, compositional analyses should be performed. Thus all the samples used for metallographic analysis in this study were also analysed for composition.

The concentration on bronze composition is also partly responsible for the lack of structured metallographic analyses, given the consequent preference for drilled samples, and even those studies where solid samples were taken tend to have concentrated on the chemical composition to the detriment of the very detailed information on manufacture, and post casting treatment in particular, which is available from metallography.

It is intended, in the current study, to reverse the past emphasis on composition and to exploit the full range of information concerning the history of the weapons which metallography can reveal. The metallurgical analyses will be used, in conjunction with experimental results, typological and distributional information, to interpret the evidence which the weapons provide.

1.6 British LBA Weapons in Museum Collections

The major collections of bronze artefacts stem from late 18th/early19th century roots when the interest of amateur scholars in matters prehistoric was stimulated both by increased discoveries of the artefacts of ancient civilisations in the Near East and by the growing awareness of the depth of the time frame in which prehistory was set. Antiquarian collections were, eventually, acquired by various museums, most notably the British Museum and the National Museum of Scotland, and, since the turn of the 20th century, the vast majority of artefacts discovered have found their way, by discovery, donation or acquisition, into museum collections.

The earlier entries into the museum collections frequently suffer from having a very sparse and unsatisfactory history. Many passed through the hands of dealers before reaching scholarly hands and provenances are often missing, or dubious in the extreme. Even when a respected organisation set out directly to acquire artefacts the use of intermediaries could cloud the issue. The Cambridge University Museum of Archaeology and Anthropology, for example, often specified the precise areas from which it was interested in acquiring particular types of artefact and, unsurprisingly, the dealer concerned usually produced the required goods from the appropriate areas in very short order (CUMAA Catalogue of Bronze Age Metalwork from the British Isles - in prep.). Even in Scotland the collections contain a number of artefacts with little or no provenance despite the considerable benefit derived from the different legal requirements for reporting and acquiring finds.

There is bound to be considerable bias in the collections towards complete and attractive objects. Indeed these are the only ones likely to have survived from finds made before the mid nineteenth century, except perhaps where the sheer quantity of metalwork found in one site was impressive in its own right. The differential in post discovery preservation does favour weapons as opposed to more mundane categories of artefact, given that society persists in attributing a certain glamour to warfare and its tools, and this must be borne in mind when contemplating the prevalence or otherwise of weapon deposits in any period.

The shift in ownership of archaeological objects from private to public hands has increased the information available concerning the overall quantity and nature of such objects. However, the number of museums has mushroomed over the years and the recent, in many respects laudable, tendency to preserve artefacts within the locality where they were discovered makes it more difficult and costly to establish the whereabouts of objects, to study broad categories thereof and to estimate the total population available for study.

At the start of this study it became clear that the published information would be insufficient to ascertain the numbers of Late Bronze Age weapons in existence. The bulk of the sword population had been adequately catalogued (Colquhoun and Burgess 1987) as had many categories of Early and Middle Bronze Age artefacts (e.g. Trump 1962) and a number of institutions have published, or were in the course of publishing, catalogues of their own collections but a comprehensive listing of the spearheads had not been published and many undiagnostic partial weapons had been excluded from the published lists. Since it would be impossible within the envisaged time frame to examine all of the weapons in the detail required it was necessary to have some idea of the available population and its whereabouts.

1.6.1 Data Collection

It was decided to design a basic questionnaire and send it to as many museums as possible to determine what their holdings of Bronze Age weapons were and their availability for further study. The questionnaire, shown in Figure 1.6.1, was designed to ascertain as much information as possible without being so detailed as to discourage completion. Several factors were bound to be subject to differences in interpretation. The most obvious was the ability to determine the precise period of the artefact, which would be done as a matter of course in the major institutions but not necessarily elsewhere. It was therefore decided to cover the entire Bronze Age since the swords were an obvious single category and the relative proportions of spearheads of the Early, Middle and Late Bronze Age could be ascertained approximately from examination of the large collections. Indeed a considerable number of spearheads likely to be deemed 'Middle Bronze Age' but contemporary with swords were of direct relevance to the investigation. Another problem anticipated was the ongoing debate as to what constitutes a weapon. Thus the 'other' category on the questionnaire not only permitted those who wished to consider axes as weapons to include this information, as well as allowing for the occasional halberd to be mentioned, but also implied strongly that some explanation of the entry was required and this was, indeed, generally given.

The boxes for the numbers were designed to allow for fragmentary artefacts in that the 'None' category implied no items whatever but the numerical categories, especially the '0-5' category, allowed for fragments to be included. Whether or not this subtlety was clear to all the respondents remains a mystery, though a number shown to possess diagnostic fragments of swords in the published literature seem to have ticked the 'None' box indicating that it was lost on at least some. Since it was intended to examine the largest collections the 'over fifty' category was intended merely to identify these.

The majority of the respondents were able to circle a category for the percentage having some form of provenance and the vast majority of those who did chose the 80-100% level. However a significant minority fell into the 40-60% and 60-80% categories, mostly explained by having acquired antiquarian collections with limited or dubious documentation.

The questionnaires were sent out in two batches with a covering letter and a stamped addressed envelope for the reply. The first batch incorporated most of the major collections and those from this batch who did not reply within three months received reminders. As a result the response rate was relatively good and many of the replies included additional information, helpful references, copies of articles and even unpublished catalogues. Replies were received from 167 museums, including a number replied for by other museums or 'umbrella' organisations, and only 21 did not respond.

On comparison of the data thus collected with Colquhoun and Burgess' (1988) listing of swords by museum, 33 institutions, for which no questionnaire had been received, holding at least one identifiable sword fragment were identified. It was decided to use the sword holdings published in conjunction with factors established from the returned questionnaires and the collections examined to estimate the numbers for these.

1.6.2 Estimation of Sword Population

Using the questionnaires, from those museums reporting numbers rather than number ranges, and the actual numbers examined, from the major collections at Cambridge University (CUMAA), the National Museum of Scotland (NMS) and the British Museum (BM), the totals of swords reported were compared with the numbers given in Colquhoun and Burgess' (1988) volume (PBF). The PBF numbers were adjusted for the collections examined to exclude unprovenanced swords from the BM listing and to allow for some swords not present when the collections were examined. The results are shown below:

	Sword Numbers Reported/Examined	Sword Numbers Listed in PBF
Museum Questionnaires	164	99
CUMAA	55	35
NMS	101	73
BM	218	106
Total	538	313

The ratio of reported/examined to listed, 1.7:1, was then applied to the numbers given in the PBF for those museums without completed questionnaires (Q) and the result rounded down to provide estimated total numbers of swords for these institutions. The ratio was also used to generate rules to approximate values (N) for those questionnaires which did not insert actual numbers as follows:

a: If $n_{PBF} = 0$ and Qe = 1-5, N = 1

b: If $n_{PBF} = 1$ and Qe = 0-5, N = 1

c: If $5 > n_{PBF} > 1$ and Qe = 0-5, N =Min[5, n_{PBF}x1.7 (rounded down)]

d: If $n_{PBF} < n_2$ and Qe = n1-n2, N = Max[n_1, Min{n_2, n_{PBF}x1.7 (rounded down)}]

e: If $n_{PBF} > n_2$, N = n_{PBF}

Where n_1 = start of number range, n_2 = end of number range, n_{PBF} = number listed in PBF and Qe = questionnaire entry.

The resulting total for swords, and parts thereof was 1466, which included approximate figures for the huge Isleham hoard and the recently discovered Waterden hoard. This may be compared with the 783 swords listed in the PBF volume. The number examined, some 499, therefore represents approximately 34% of the estimated total.

1.6.3 Estimation of Spearhead Population

A similar procedure was followed in estimating the spearhead population. Using the questionnaires from those museums reporting numbers rather than number ranges and the actual numbers examined from the collections at CUMAA, NMS and the BM, the total swords reported were compared with the total spearheads reported. The results are shown below:

	Sword Numbers Reported/Examined	Spear Numbers Reported/Examined
Museum Questionnaires	164	426
CUMAA	55	172
NMS	101	168
BM	218	340
Total	538	1106

The resulting ratio of spearheads to swords, 2.1:1, was then used on the estimated sword figures (S) for each institution, directly in the case of those where no completed questionnaires existed and according to the following rules where only a category had been given on the questionnaire:

a: If S = 0 and Qe = 0-5, N = 1

b: If S = 1 and Qe = 0-5, N = 2

c: If S > 1 and Qe = 0-5, N =Min[5, Sx2.1 (rounded down)]

d: If Qe = n_1-n_2, N = Max[n_1, Min{n_2, Sx2.1 (rounded down)}]

The resulting total for spearheads and identifiable parts thereof was 2645, including estimated figures for the Isleham and Waterden hoards. The number examined, some 690, therefore represents approximately 26% of the estimated total. The difference between this and that for swords is largely due to the fact that only swords, which were shortly thereafter to be put on display, were examined at the Museum of London.

The estimate for the spearhead population includes those from the entire Bronze Age, as do the numbers examined, and it is necessary to estimate the population relevant to the period under consideration by means of typological classification of those examined. The assignation of periods to all but the earliest types is far from precise, since different types seem to have been contemporary even within small geographic regions and may well have been designed for different purposes and/or have been made by a different category of metalworker.

I have therefore excluded only the obviously very early, generally unsocketed, types and the socket looped types from my figures for the period. Even in the case of the latter it is not clear that they did not persist into the Late Bronze Age, though the majority with associations do appear to predate the arrival of swords.

2 Microstructural and Compositional Analyses

2.1 Sampling Criteria

Metallographic examination reveals the microstructural results of the processes used to make artefacts and bronze, which is relatively robust with respect to corrosion, is well suited to such visual examination. Given the understandable reluctance of museum curators to subject artefacts to any form of destructive sampling it is impossible to achieve the metallographic ideal of cutting several relatively large samples from every artefact. It is only in the last quarter of this century, mainly in the fields of archaeology, art provenancing and museum conservation that the use of tiny samples has been introduced. Plate 2.1 shows two sword blades after sampling for this study, superimposed on the blade edges before sampling. Two Palestinian daggers, which were subjected to 'industrial' style metallurgical sampling over twenty years ago, are shown for comparison.

Very small samples, such as the sword samples shown, do yield less information about each individual object, given the potential heterogeneity of Bronze Age castings, but the examination of small samples taken from a large number of artefacts can be a valuable source of information. Not only should the distribution of the results of quantitative metallographic examination of such samples adequately represent the distribution to be expected from the population as a whole but any differences in characteristics between different groups should be reflected in the distributions derived from the data for those groups.

The decision to request samples from weapons in the museum collections was taken for a number of reasons:

> Although a number of the weapons had been sampled in the past for compositional analysis, there were remarkably few solid samples available, particularly from swords, from which the microstructures could be ascertained. Thus, in order to perform any statistical analyses of metallographic findings, especially on a regional basis, a substantial number of samples from different regions of the country were required.
>
> The proposed experimental edge damage reproduction programme meant that it was essential to obtain a realistic representation of the range of microstructures and compositions which was present among the archaeological artefacts. The

experimental edges had to be produced in such a way that they fell within the 'normal' range of the archaeological samples so that the behaviour of the metal edge when impacted would be comparable with that of the archaeological weapons.

It was also essential, in as far as possible, to control the sites from which the solid samples were cut so that they were comparable from one blade to another and represented the areas of blade which were to be replicated for the experimental programme. Since the cutting edge would almost certainly be the most heavily worked area of a weapon, it was particularly important to examine the microstructure of that area. In the light of observed variation in composition, across certain blades with high lead content (Hughes, Northover & Staniasek 1982) the differences in composition between the centre and the edge of the blade could also be substantial.

The artefacts from which metallographic samples were to be cut were not selected randomly since the research aim demanded a sufficient number of samples from each broad geographic zone of the country to enable statistical analyses to be performed. The relatively small number of swords from Western Britain meant that efforts had to be made to include as many of these as possible. Thus an initial stratified sample was constructed with random sampling within broad geographic areas. Since by far the most common and widespread sword type in Britain is the Ewart Park grouping (Colquhoun & Burgess 1988, 55-68), the majority of the swords considered for sampling were of this type.

The initial lists were revised, after consultation with the relevant museum curators, both in the light of the reluctance to damage items potentially required for display purposes and of the usefulness of the information to be gained from the sampling. In particular it was suggested that extra information could be derived by sampling swords which had already had compositional analyses performed using drillings from within the body of the artefact. These previous analyses could then be compared with those of the metallographic samples cut from the edges, which were to be analysed for composition using electron probe microanalysis (EPMA), which is a non-destructive method.

As a result of the above processes it would be hard to describe the sample of swords selected for metallographic sampling as random in any strict statistical sense. However, faced with the difficulties involved in obtaining samples and the fact that the underlying population, of Bronze Age swords deposited in antiquity, retrieved in modern times and donated to or bought by museums, is likely to be a far from unbiased sample of the universe of Bronze Age swords, it was felt to be satisfactory for the purposes of the research.

In order to ensure comparability between samples all 72 were taken from undamaged edges at approximately the equivalent point on each sword, which was as near to the widest part of the blade as possible. Modifications from the ideal position had to be made to allow for existing edge damage, for blades which had been broken and for the preferences of curators, who were involved throughout the process.

These criteria did not match those applied when cutting the 74 sword samples, which included 5 from sword hilts, previously taken for studies of composition and trace element distribution, which were lent to me by Dr J.P. Northover. Many of these samples had, deliberately, been taken from damaged areas of the artefacts and, although most had come from blade edges, the position sampled was rather more random. Fortunately, most appeared, on examination, to have come from the heavily worked area of the blade edge and distortions to the microstructure caused by impact were visible. The effect of distortions caused by damage to the artefact on the results of the analyses could therefore be substantially reduced. Certain population statistics derived from the metallographic examination of the samples were also tested but no relevant statistically significant difference between the two groups was found once the effects of area or typological bias were eliminated.

All except one of the 56 spearhead samples examined came from Dr Northover's collection and these, like the borrowed sword samples, came from a variety of locations on the spearheads, often from damaged areas, although the majority did come from the blade edges. As no attempt was to be made to replicate spearheads for experimental purposes the extent of control over sampling was less vital and no programme of systematic sampling of spearheads was undertaken. The typological grouping for spearheads will be discussed in detail in Chapter 4.3.1 below but, for the purposes of metallographic and compositional analyses, the spearheads found in association with swords from a particular typological grouping have been deemed to belong to that grouping. Typological grouping, as described in Chapter 1.2, is here used to place the weapons chronologically in line with the system illustrated in Figure 1.2.

2.2 Method

The intent to mount all of the sword samples with the cross-section of the blade perpendicular to the edge uppermost proved quite difficult to achieve since the samples were very light and a few were dislodged during mounting. The borrowed samples had in effect been mounted randomly since compositional analyses are not affected by sample orientation, although many had actually come to rest with the 'correct' face uppermost. The use of those samples where this did not occur clearly will have some effect on the results of the subsequent analyses, most notably those where the visual effects depend on the plane of the section, such as the distortion of inclusions, and this must be taken into account when assessing their relevance.

All samples analysed were hot mounted in a conductive medium (bakelite impregnated with graphite) to facilitate subsequent use of EPMA. Although the use of hot mounting is not ideal for metallographic samples, the temperature attained during mounting, being below 200^{o}C, is sufficiently low as to have no appreciable effect on the microstructure. The advantages of hot mounting for such small samples was felt to outweigh any disadvantages since the medium used is much more akin to the metal in terms of hardness, making subsequent polishing much easier, edge retention is substantially better than in many of the cold setting compounds and very small samples are more difficult to locate securely in cold setting compounds.

The mounted samples were ground on a wet grinding wheel using 800, 1200 and 2500 grit papers. Coarse grinding was kept to the bare minimum required due to the danger of removal of such small samples (all were less than 2mm thick) which can disappear very rapidly. The samples were then polished on a wheel using diamond pastes of 6, 3 and 1 micron. Some modification had to be made to normal polishing procedures to minimise the smearing and/or removal of lead which was a problem throughout. It was found that use of a napped cloth was not helpful, although this normally gives a better finish to the final polish, as it removed rather more lead inclusions than a smooth 'paper'. The extent of surface smearing of lead decreased with practice as the downward pressure on the sample was reduced. Although these factors minimised the problem it continued to exist and there can be little doubt that, at the very least, a small proportion of the lead was removed during polishing. This is particularly relevant when dealing with the results of the compositional analyses as these were made on polished samples.

The samples were examined in the as polished state using a Nikon Optiphot-2 metallurgical microscope. The nature of corrosion, inclusions and porosity were observed, using normal and polarised light, as were the direction and extent of distortion of the structures, especially the copper sulphide inclusions. This gave some indication of the extent to which the edge had been worked. The samples were then photographed, in colour, at magnifications of 50, 200, 400 and 1000 times in order to provide both a record of the observations and to enable measurement and comparative assessment of features as required.

Etching was initially done with a standard acidified ferric chloride solution consisting of 5g $FeCl_3$, 15ml HCl and 60ml ethanol but this proved much too strong. This solution was then diluted 1:4 with ethanol and the results were much improved although it failed adequately to reveal the microstructure for a substantial number of samples. An acidified potassium dichromate solution, consisting of 2g $K_2Cr_2O_7$, 4 drops HCl, 8ml H_2SO_4 and 100ml H_2O, gave much better results and was used for the all the samples where the results with ferric chloride had proved unsatisfactory and for all the borrowed samples. The need to minimise the risk of having to re-polish such small samples meant that only a light etch was given and the use of polarised light was generally necessary to examine the microstructures revealed.

The etched samples were examined to determine the presence and extent of the different phases, the nature, shape and size of the grains, and the presence of annealing or mechanical twins and strain lines. Each sample was then photographed at magnifications of 50, 200, 400 and 1000 times, with particular emphasis on the magnification at which the grain structure showed most clearly.

The nature of the samples was such that it proved impossible to apply any sophisticated methods to measure grain size. The lack of homogeneity in the metal meant that the etch was not even across the entire surface of the sample while the presence of corrosion in a number of samples severely interrupted the grain pattern. Moreover, some of the most heavily worked samples had a very distorted grain structure with considerable directional bias. Grain size was eventually estimated by calculating the mean size of a sample of grains measured directly from the photographs. This meant that the standard deviation for each sample was available to give a measure of the variability of grain size within the sample but dividing the population into high and low variability groups according to the ratio of the standard deviation of the mean grain size to the mean grain size did not yield any statistically significant differences. (Bridgford 1998, 210)

After metallographic examination hardness measurements were made using a Leco M400 Microhardness Tester, with 50g load and 15 second indent time. The measurements were made on three different areas of each sample, avoiding inclusions, porosity, corrosion and eutectoid where possible, and the results were averaged. Where the orientation of the sample was clear, the measurements were made in the area corresponding to the outside edge of the sword blade, the base of the sample, i.e. the area of the sample furthest in towards the midrib of the sword, and the centre of the sample. (Bridgford 1998, 212)

The new sword samples were then sent to the Department of Materials, University of Oxford, to be analysed for chemical composition. This was done by Dr J.P. Northover with an electron micro-probe using wavelength dispersive spectrometry, the same method as had been used on the sword and spear samples borrowed from Dr Northover. At least three readings were taken for each sample and the results averaged in order to compensate for the heterogeneous nature of the metal.

2.3 Microstructural Characteristics

Most features were assessed on a comparative scale to facilitate further analysis. The only features amenable to fully quantitative analysis were the hardness and the average grain size and, due to the complex distribution of the latter, it proved preferable to group the data for this characteristic as well. Where possible the distribution of the characteristics was analysed statistically to assess where there were significant differences. The Chi-squared test (Shennan 1988, 65-76) was used for the grouped characteristics and differences in means were tested using Student's t-distribution (Shennan 1988, 306). All tests were made using a 5% significance limit, i.e. the null hypothesis, that underlying distribution or actual means were the same, was not rejected unless the test showed a difference which had a probability of less than 5% of occurring if the null hypothesis were true.

The differences between distributions of microstructural characteristics of weapons from the four different regions, defined in Chapter 1.1.4 above, were assessed. The number of sword samples available from the Western region was considerably lower than those from the other three regions, which caused some problems for the statistical analyses, particularly when dealing with individual typological groupings. When assessing possible differences in microstructure between typological groups of weapons, the very low number of Late samples meant that this group could not be considered alone in the statistical analyses and the low number of Early samples also precluded some statistical analyses, especially when consideration was restricted to the individual regions. The difficulties involved in assigning typological groupings to particular periods are discussed further in Chapter 4, particularly in the case of spearheads where the simple lanceolate socketed spearhead appears to have been prevalent throughout the five hundred years considered herein. The bulk of the spearhead samples were from the South East and, in order to eliminate any regional differences, these were generally compared with the sword samples only overall and within that region.

Certain very characteristic microstructural features were evident on samples taken from two large hoards, Wilburton and Duddingston Loch, which are known to have been burnt. These include very large equiaxed grains and fully homogenised metal, typical of excessive annealing, and areas of high porosity and corrosion. Some examples are shown in Plate 2.3. Since the inclusion of large numbers of such samples would affect the distribution of microstructural characteristics which arose from manufacturing techniques, analyses were made on the distributions of characteristics shown by the samples from all weapons and from all weapons excluding those with a microstructure closely resembling that exhibited by samples from those hoards, that is those weapons assumed to be burnt. The topic of these burnt weapons will be further discussed in Chapter 5.

The significance of the regional distributions of those microstructural characteristics, which resulted largely from the finishing treatments applied to the weapons, will be discussed in Chapter 6 below, in the context of other evidence, particularly in relation to metalworking and weaponry, of regional differentiation within Britain.

2.3.1 Porosity

The amount of porosity was assessed on a scale from 1, no porosity visible, to 5, very heavy porosity visible. Examples from each group are shown in Plate 2.3.1.

Many castings will show some shrinkage porosity in a dendritic pattern but hammering will close up the voids and, eventually, eliminate them. Porosity due to gas being trapped during the cast often causes small round holes which may also be closed by hammering but more severe gas porosity can be catastrophic, causing large voids in the metal (Bailey 1960, 388). A well cast and hardened edge, such as would be expected on a sword, should show relatively little porosity, while a poorly cast artefact is likely to show large voids within the metal and, if it survives the finishing process, could easily break during use.

The measure of porosity thus reflects not only the quality of the casting but the extent of working applied during finishing. Categories 1 and 2 therefore reflect well cast objects, differentiated mostly by the amount of deformation due to hammering. The third category includes samples showing considerable shrinkage porosity and those with limited gas porosity while categories 4 and 5 show more substantial shrinkage and gas porosity, which in the latter case would be very likely to cause failure in use. Although most of the holes in the metal of the samples are clearly due to porosity it is possible that removal of segregated lead during the polishing process (as discussed in Chapter 2.2 above) may exaggerate the visible porosity.

Figures 2.3.1(i)-(iii) show the distribution of porosity regionally, by typological grouping and by weapon category for all samples, excluding those exhibiting a 'burnt' microstructure. Figure 2.3.1(iv) shows the distribution for Ewart Park sword blades, excluding those exhibiting a 'burnt' microstructure. Table 2.3.1(i) summarises the data by region and typological grouping for all weapons and Table 2.3.1(ii) summarises the regional data for particular typological groups.

The Chi-squared test, with 5% significance limit, was used to assess differences in visible porosity. The Chi-squared statistics for those tests where numbers differed significantly from those expected are set out in Appendix 1. The use of the word significant in the discussion which follows should be taken to mean statistically significant in all cases.

The only statistically significant regional difference in distribution lay in the East Anglian proportion in the two groups showing least porosity, which was significantly higher than that in other regions. The exclusion of burnt weapons underlined this result, as can be seen in Figure 2.3.1(i).

When the data are analysed for swords alone the difference beween East Anglian proportions and those from other regions, although still clear, ceases to be statistically significant. This may be explained by the fact that only 5% of the spearheads came from East Anglia and that spearhead samples had significantly greater porosity than swords both overall and in the South East. Thus the effect of the inclusion of the spear samples was regionally differentiated, with little effect on the proportion of high and low porosity samples from East Anglia but substantially increasing the proportion of high porosity samples elsewhere.

The regional distribution for Ewart Park swords in Figure 2.3.1(iv) exhibits once again an East Anglian tendency to low porosity and a Western tendency to higher porosity, although the numbers in the groups were too low to show statistical significance.

There were no statistically significant differences when the distribution according to typological grouping was analysed. However, although the numbers examined were too small to merit statistical consideration, all the Late weapons were in the low porosity categories while the Early weapons were approximately equally split between low and high porosity categories, as can be seen in Figure 2.3.1(ii)

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Comparison of the distributions of porosity categories between Ewart Park and Wilburton sword samples in both the South East and East Anglia showed no significant difference, despite a slight bias towards the lower categories in Ewart Park sword samples.

The main result from analysis of porosity in the samples is the clearly significant tendency to higher porosity in spear and hilt samples when compared with sword blade samples as shown in Figure 2.3.1(iii). This is most likely to be due both to a poorer quality of casting and to less hammering of spear edges and hilts. Hilts were clearly the last part of the mould to be filled during casting for most swords given that porosity within the hilt is generally much more severe than within the blade of the same sword.

Although there were some regional and some possible chronological variations none was sufficiently strong to exhibit significance given the numbers of samples analysed.

2.3.2 Distortion of Inclusions

Inclusion distortion was also assessed on a 5 point scale from 1, no distortion visible to 5, inclusions seen as 'strings', either still complete or broken up, orientated in the same direction within the metal. Examples from each group are shown in Plate 2.3.2.

Inclusions were not analysed for chemical composition during this study but, by visual comparison with samples where inclusions have been so analysed, it was clear that the vast majority were copper sulphide. Inclusions of copper sulphide retain their distortion from the spheroid and are largely unaffected by annealing. They therefore provide an indication of how severely the metal has been deformed from its original cast shape. The morphology of most sulphide inclusions should not be affected by burning but, at temperatures in excess of 813^{o}C, where sulphur concentration is high, the copper/sulphur phase diagram reveals a liquid phase and this may cause changes.

Inclusion distortion is one of the characteristics which is severely affected by the orientation of the sample mounting since a cut at right angles to the plane of deformation could show almost no distortion. The vast majority of samples were 'correctly' mounted and of those which were not at least a third would not have been perpendicular to the plane of deformation. Thus, although the overall numbers of samples with 'severely' distorted inclusions is likely to be understated, the effects should be random and have little or no effect on comparisons between different groups.

Figures 2.3.2(i)-(iii) show the distribution of inclusion distortion regionally, by typological grouping and by weapon category for all samples, excluding those exhibiting a 'burnt' microstructure. Figure 2.3.2(iv) shows the distribution for Ewart Park sword blades, excluding those exhibiting a 'burnt' microstructure. Table 2.3.2(i) summarises the data by region and typological grouping for all weapons and Table 2.3.2(ii) summarises the regional data for particular typological groups.

The Chi-squared test, with 5% significance limit, was used to assess differences in distribution of inclusion distortion. The Chi-squared statistics for those tests where numbers differed significantly from those expected are set out in Appendix 1. The use of the word significant in the discussion which follows should be taken to mean statistically significant in all cases.

The East Anglian proportion in the two groups showing most distortion was significantly higher than that in other regions both including and excluding burnt weapons. The exclusion of burnt weapons meant that the low proportion of South Eastern samples in the two groups showing most distortion was also statistically significant as can be seen in Figure 2.3.2(i).

None of the variation in distribution by typological grouping shown in Figure 2.3.2(ii) proved statistically significant. The vast majority of Early swords were classified in categories 3, 4 and 5 but 40% of the Late swords were classified in categories 1 and 2, showing very little distortion.

When considered separately there were no statistically significant regional differences in the distribution of inclusion distortion for Wilburton swords but the relative preponderance of inclusion distortion in East Anglia remained significant when considering Ewart Park swords alone both including and excluding samples with burnt microstructures, as shown in Figure 2.3.2(iv).

The distribution of inclusion distortion among spearheads showed a marked tendency to high proportions in categories rated 2 and 4 and much lower proportions rated 3 while only one spearhead appeared in the highly distorted category 5. This contrasted with the distribution for swords where around 12% of samples fell into category 5 and the proportions in categories rated 2, 3 and 4 were much more similar. When South Eastern swords and spearheads were compared directly the differences were not statistically significant. Figure 2.3.2(iii) also shows that two of the five hilts examined showed substantial inclusion distortion, which may have been due to damage caused during breakage or to efforts to remove scars left after fettling.

Bearing in mind the comments above concerning the likely underestimation of distortion caused by the orientation of the sample, it is clear that, at the very most, only 15% of sword and 24% of spearhead samples had no distortion of inclusions, that the proportions which were actually undeformed are likely to be very substantially lower than these and that sword samples were more likely to have been very heavily deformed and less likely to show no deformation at all than spearhead samples. It is also clear that East Anglian sword samples showed a greater tendency to have highly deformed inclusions than those from other areas.

2.3.3 Corrosion

The extent and severity of corrosion was assessed on a 4 point scale ranging from 1, virtually free from corrosion, to 4, severe internal and external corrosion. Examples of each are shown in Plate 2.3.3(i).

While it is generally difficult to identify the chemical composition of the corrosion compounds visually, some can show up with very characteristic colours using an analyser with polarised lighting, although this may be affected by orientation or by mixing with other compounds. Cuprite is one of the most easily identified, giving a scarlet colour, but most corrosion areas will show a wide range of colour variation. Examples from two of the samples examined are shown in Plate 2.3.3(ii).

The major external factors affecting corrosion are the conditions in which the artefact was deposited, including the chemical composition and moisture content of the medium in which it was contained, the changes in conditions to which it was subjected during burial and, usually more importantly, after discovery. The chemical composition of the alloy, in particular the presence of high levels of lead and high tin phases, is also of considerable importance. It has been proposed (Northover - pers. comm.) that the original lead content of Late Bronze Age alloys may be estimated by assessing the extent of corrosion related thereto. Aspects of the microstructure will affect the extent of corrosion which can penetrate along strain lines, in metal which has been substantially hardened, and along grain boundaries and porosity voids.

Figures 2.3.3(i)-(iii) show the distribution of corrosion regionally, by typological grouping and by weapon category for all samples, excluding those exhibiting a 'burnt' microstructure. Figure 2.3.3(iv) shows the distribution for Ewart Park sword blades, excluding those exhibiting a 'burnt' microstructure. Table 2.3.3(i) summarises the data by region and typological grouping for all weapons and Table 2.3.3(ii) summarises the regional data for particular typological groups.

The Chi-squared test, with 5% significance limit, was used to assess differences in visible corrosion. The Chi-squared statistics for those tests where numbers differed significantly from those expected are set out in Appendix 1. The use of the word significant in the discussion which follows should be taken to mean statistically significant in all cases.

Although the proportion of samples showing the two lowest levels of corrosion was clearly higher in East Anglia than elsewhere this was only statistically significant if burnt weapons were excluded, as shown in Figure 2.3.3(i). The rather high proportion of more heavily corroded samples from the West was not statistically significant. When swords alone were considered the pattern was similar but there were no statistically significant differences, even when burnt swords were excluded.

The differences in corrosion levels according to typological grouping shown in Figure 2.3.3(ii) were not statistically significant. Wilburton swords showed some tendency to having greater corrosion than Ewart Park swords but differences were not significant. The tendency of spears to show more corrosion than swords was significant, both overall and in the South East alone, whether or not burnt weapons were included.

The effects of regionality on corrosion levels were surprisingly limited given the effect of burial conditions on this characteristic. However the West did show signs of a tendency to greater corrosion and East Anglia to less. The figures excluding burnt weapons are probably more relevant for this characteristic given that burning is likely to lead to increased corrosion. It is clear from Figure 2.3.3(iii) that spearhead samples and sword hilt samples, which tend to suffer from excess porosity as noted in Chapter 2.3.1 above and from heterogeneity as noted in Chapter 2.3.4 below, were inclined to be more corroded than the sword samples and the effect is unlikely to be entirely due to the relative preponderance of samples from damaged parts of the weapon within the groups of spearhead and hilt samples.

2.3.4 High Tin Phases

The high tin delta phases are often visible as pale blue areas in the polished metal but are more fully revealed in the etched sample. The alpha plus delta eutectoid, also pale blue, generally shows internal structure when etched. The presence of such high tin areas was assessed on a 4 point scale ranging from 1, none visible, to 4, a substantial network of alpha plus delta eutectoid or delta phase throughout the sample. Etched examples from each of categories 1 to 3, together with an example, both etched and unetched, from category 4, are shown in Plate 2.3.4.

The presence of the eutectoid or the delta phase should, in theory, require a tin content in excess of 8% (Scott 1991, 171) but the heterogeneity of the bronze and unevenness of cooling in these archaeological specimens frequently leads to their presence even in bronzes with a somewhat lower overall tin content. Lengthy annealing at temperatures in excess of 600°C should remove such phases in bronzes containing up to approximately 15% tin but rapid low temperature annealing can leave high tin phases substantially unchanged. The presence of these hard brittle phases is considered detrimental to the mechanical properties of the metal but, if sufficiently small volumes are dispersed evenly throughout the microstructure, they do not appear to preclude substantial deformation by cold working. The presence and extent of these phases indicates the tin content of the alloy, the cooling rate of the cast and the thoroughness of the annealing processes which it has undergone.

Figures 2.3.4(i)-(iii) show the distribution of high tin phases regionally, by typological grouping and by weapon category for all samples, excluding those exhibiting a 'burnt' microstructure. Figure 2.3.4(iv) shows the distribution for Ewart Park sword blades, excluding those exhibiting a 'burnt' microstructure. Table 2.3.4(i) summarises the data by region and typological grouping for all weapons and Table 2.3.4(ii) summarises the regional data for particular typological groups.

The Chi-squared test, with 5% significance limit, was used to assess differences in visible areas of high tin delta phase and alpha plus delta eutectoid. The use of the word significant in the discussion which follows should be taken to mean statistically significant in all cases.

The most appropriate figures are obviously those which exclude burnt weapons but, even when these are used, there were no significant distributional differences between areas for any weapon type nor were there any statistically significant differences between swords and spears. High tin phases will be more prevalent in areas of metal which have not been annealed and this may explain the high proportion of the small group of sword hilt samples with substantial areas of such phases, shown in Figure 2.3.4(iii). The fact that the vast majority of samples showed an alloy whose tin content fell within the range in which high tin phases can occur and the essentially random nature of the conditions leading to their formation is reflected in the data. Indeed the samples were almost equally split between those with little or no sign of high tin phases and those with obvious areas thereof.

2.3.5 Coring & Recrystallisation

The use of etchant reveals the presence of grains, whose different orientations and boundaries affect the degree to which the etchant attacks the metal surface. Coring, which exists as a result of changes in composition of the metal as it freezes, also affects the attack of the etchant. These characteristics indicate the extent to which the artefact was heat treated after casting. As the presence of recrystallisation and of coring are strongly negatively correlated these two characteristics were assessed together on a 5 point scale.

Category 1 covered those samples with total recrystallisation and no residual coring indicating complete annealing which has caused the metal to lose all trace of the uneven dendritic structures and the coring of grains which result from the differential concentration of tin in solution during the initial cooling after casting. Category 2 covered samples which showed complete recrystallisation but which had slight traces of remnant coring. Category 3 comprised fully recrystallised structures with substantial remnant coring, often striated within the metal by subsequent working. Category 4 covered those samples with partial recrystallisation, generally towards the surface of the metal, with some residual large as-cast grains, often containing dendrites and substantial coring. Category 5 comprised those samples showing no recrystallisation whatever, which generally showed both dendrites and substantial coring. Examples of each are shown in Plate 2.3.5.

Figures 2.3.5(i)-(iii) show the distribution of coring and recrystallisation regionally, by typological grouping and by weapon category for all samples, excluding those exhibiting a 'burnt' microstructure. Figure 2.3.5(iv) shows the distribution for Ewart Park sword blades, excluding those exhibiting a 'burnt' microstructure. Table 2.3.5(i) summarises the data by region and typological grouping for all weapons and Table 2.3.5(ii) summarises the regional data for particular typological groups.

The Chi-squared test, with 5% significance limit, was used to assess differences in distribution of coring and recrystallisation. The Chi-squared statistics for those tests where numbers differed significantly from those expected are set out in Appendix 1. The use of the word significant in the discussion which follows should be taken to mean statistically significant in all cases.

The proportion of weapons giving samples which were not fully recrystallised (categories 4 and 5) was particularly low in East Anglia (under 10%) and high in the West (over 30%), whether or not burnt weapons were excluded, but since the numbers concerned were relatively small no statistical significance could be established. Regional differences between the proportions of obviously cored (categories 3, 4 and 5) were more limited, although the proportion in the West was rather high. Exclusion of burnt samples changed this quite dramatically in that the numbers of uncored samples in East Anglia and Scotland fell relatively sharply bringing these areas into line with the West and leaving only the South East with approximately 50% more in categories 1 and 2 than in the three obviously cored categories while all other regions showed the reverse proportions. This difference, shown in Figure 2.3.5(i), was statistically significant. Although the pattern for swords taken as a separate group was similar to that above the differences were not statistically significant.

There were no statistically significant differences between the typological groupings in the relative proportions of cored and uncored or recrystallised and unrecrystallised samples, as can be seen in Figure 2.3.5(ii).

There was a slight tendency towards a lower proportion of relatively uncored samples for Wilburton as opposed to Ewart Park swords and a relatively high proportion of the small group of samples from Early swords were not recrystallised, while all Late sword samples were fully recrystallised.

Within the group of Ewart Park swords, shown graphically in Figure 2.3.5(iv) it is notable that all of the East Anglian samples were fully recrystallised and that the Scottish and East Anglian samples are heavily concentrated in the two groups which, although fully recrystallised, show some coring.

The proportion of spear samples which were not fully recrystallised was significantly higher than for swords, as may be seen from Figure 2.3.5(iii), with or without considering samples with a typical burnt microstructure. The five sword hilts were all recrystallised, with some coring, indicating that annealing processes were likely to have been applied to the entire sword and not just the blade.

It would appear from the data that spears were less likely to have been annealed than swords and that some geographic influences probably existed with the practices in the South and East likely to include more substantial annealing than elsewhere and Western metal workers being more likely to forego such procedures. The possibility of an element of chronological influence exists but is not clear from the available data.

2.3.6 Distortion of Grains

Grain distortion was assessed on a 3 point scale. Category 1 comprised those samples where the grains were equiaxed and showed no distortion whatever. Category 2 included all samples which showed some grain distortion from the equiaxed, and distortion of dendritic structures in those samples which were not recrystallised, but where the distortion was not great or where substantial areas showed little or no distortion. The samples included in Category 3 were those where the grains were substantially deformed, generally showing strain lines and bent twins. Examples of each category are shown in Plate 2.3.6, and the measured hardness levels are also shown.

This is another characteristic which may be affected by the plane of the sample mounting. It is also clearly subject to the effects of prolonged exposure to high temperatures after manufacture. Indeed almost all the samples classified in Category 1 fitted the criteria for having come from burnt weapons.

The great variabilty of the structure within each sample, the uneven etching caused by lack of compositional homogeneity and the fact that comparisons often had to be made at maximum magnification in order merely to reveal the grains, meant that further subdivision of the large group of samples in the middle category proved impossible. This was disappointing as this characteristic is the visible indication of the extent of work hardening applied to the metal after the final anneal and further subdivision, if valid, would have been useful.

Figures 2.3.6(i)-(iii) show the distribution of grain distortion regionally, by typological grouping and by weapon category for all samples, excluding those exhibiting a 'burnt' microstructure. Figure 2.3.6(iv) shows the distribution for Ewart Park sword blades, excluding those exhibiting a burnt microstructure. Table 2.3.6(i) summarises the data by region and typological grouping for all weapons and Table 2.3.6(ii) summarises the regional data for particular typological groups.

The Chi-squared test, with 5% significance limit, was used to assess differences in distribution of grain distortion. The use of the word significant in the discussion which follows should be taken to mean statistically significant in all cases.

As can be seen in Figure 2.3.6(i), the samples showed considerable regional variation with approximately 30% of East Anglian and 20% of South Eastern samples falling into the third, heavily distorted, category, while only 10% of Scottish samples and no Western samples at all fell into this group. Low overall numbers of Western samples precluded the establishment of a statistically significant difference.

When examined separately sword samples showed very much the same regional pattern and when examination was confined to samples from Ewart Park swords, as illustrated in Figure 2.3.6(iv) the regional results were again broadly similar.

As shown in Figure 2.3.6(ii), there were no Late weapons and less than a fifth of Ewart Park weapons in the heavily distorted category. There were no significant differences between Ewart Park and Wilburton swords either overall or in the South East nor were there any significant distributional differences between sword and spears, either overall, as shown in Figure 2.3.6(iii) or in the South East.

The extent to which a weapon was hammered after its final heat treatment does seem to have varied on a regional basis but typological differences and weapon type do not appear to have had much effect.

2.3.7 Grain Size

The eight ASTM standard grain sizes proved inappropriate since the bulk of samples had such small grains that they fell into only two categories (No 7 and No 8) and it proved necessary to divide the data into groups based on the mean grain size:

Grain Size Group	Mean Grain Size (micrometers)
a	0-10
b	10-15
c	15-20
d	20-25
e	25-35
f	>35

The range of grain sizes is shown in Plate 2.3.7.

Grain sizes are the result of a complex combination of the alloy, the casting process and the post casting processes, particularly the cold working and annealing of the metal. Broadly speaking the more cold work done before annealing the smaller the ultimate grain size after annealing should be but the higher the annealing temperature and the longer the annealing time, the larger the grain size becomes. Since, for the British Late Bronze Age, the alloys used are relatively consistent and most swords appear to have been cast in clay moulds (Northover 1988, 131), the critical features on the sword edges are the cold working and the annealing conditions. These are likely to be highly consistent over periods of time if the artefacts were made by the same craftsman or by those under his supervision (Bridgford 1998, 210). Grain size has considerable effect on the mechanical properties of the metal. Very large grains reduce metal toughness and yield strength while small, evenly sized grains toughen it and would therefore be desirable in weapon edges.

Figures 2.3.7(i)-(iii) show the distribution of grain sizes regionally, by typological grouping and by weapon category for all samples, excluding those exhibiting a burnt microstructure. Figure 2.3.7(iv) shows the distribution for Ewart Park sword blades, excluding those exhibiting a 'burnt' microstructure. Table 2.3.7(i) summarises the data by region and typological grouping for all weapons and Table 2.3.7(ii) summarises the regional data for particular typological groups.

The Chi-squared test, with 5% significance limit, was used to assess differences in visible porosity. The Chi-squared statistics for those tests where numbers differed significantly from those expected are set out in Appendix 1. The use of the word significant in the discussion which follows should be taken to mean statistically significant in all cases.

The differences in distribution shapes and the multimodal nature thereof is clear from Figure 2.3.7(i). When all weapons are considered, both including and excluding those samples with burnt characteristics, there are significant differences in distribution between the West and the other regions, in particular East Anglia and the South East. This is largely because the proportion of the Western samples in Groups a and b is significantly low, less than a quarter compared with over half for the South East and East Anglia, while the proportion of samples with larger grains, particularly in Group f, is high.

Confining the comparison to those sword samples which did not exhibit burnt characteristics, yields a similar pattern to the above with the West remaining significantly more weighted towards larger grain sizes, East Anglia and the South East somewhat more inclined towards the small grain sizes and Scotland evenly balanced between the two. This pattern is also seen in Figure 2.3.7(iv) when using samples from Ewart Park swords alone.

Just over a third of Early and Late weapons were in Groups a and b, while both Ewart Park and Wilburton weapons had approximately half their number in these two categories. However the Late swords had no samples in Group f, the Ewart Park and Wilburton swords had under 5% of their total in this group and the Early swords had a third therein. Comparison of spears and swords, excluding burnt samples, as illustrated in Figure 2.3.7(iii) showed a statistically significantly higher proportion of spear samples in Group f.

There were clearly regional differences in the distribution of samples among the various grain size groupings although the distributions were rather complex. The South East and East Anglia seemed to have more of the smallest grain size samples than the West, with Scotland falling between these two extremes. There may be some element of typological differentiation, although much of this may be due to a lack of annealing among earlier groups. This could also help to explain the very high proportion of spearhead samples exhibiting large grain sizes, as these were more heavily weighted towards earlier examples than were swords.

2.3.8 Hardness

Hardness of the samples was measured directly, although the use of a micro-hardness tester was essential given the very small size of the samples. Examples showing the range of microstructures as related to the various hardness levels are shown in Plate 2.3.6, which also showed the grain distortion categories.

The hardness measurements, on the Vickers scale, ranged from the very soft, around 60HV to extremely hard, around 270HV. Those which were below 100HV were mostly the structures with very large grains, either as cast or excessively annealed, with no work hardening whatever. Those at the top end of the range, above 200HV, tended to have very small grains with a very distorted structure and many strain lines.

Where there was some variability in hardness readings within samples it was generally the part of the sample corresponding to the outside edge of the blade which gave the highest reading, although in a few cases the reading from the point of detachment of the sample was high, probably as a result of 'tearing' the metal at the base of the saw cuts to detach samples.

The variability within samples was substantial in a few cases but examination of the ratio of the standard deviation of the measurements to the average hardness for each sample show that the median ratio was only 10% with the lower quartile being 5%, the upper quartile being 15% and the maximum just over 40%. This shows that, in general, the readings taken were in a relatively narrow range despite the heterogeneity of the metal and the microstructures. The deliberate avoidance of porosity, corrosion and areas other than the main metal phase will have helped to prevent variability.

The hardness of the metal obviously affects its mechanical properties. Although it is desirable that a weapon edge be sufficiently hard to be resistant to indentation, bronze which has been excessively work hardened can be extremely brittle and is likely to splinter on impact, precluding the possibility of simple repair.

Figures 2.3.8(i)-(iii) show the distribution of hardness levels regionally, by typological grouping and by weapon category for all samples, excluding those exhibiting a burnt microstructure. Figure 2.3.8(iv) shows the distribution for Ewart Park sword blades, excluding those exhibiting a burnt microstructure. Table 2.3.8(i) summarises the data by region and typological grouping for all weapons, Table 2.3.8(ii) summarises the regional data for particular typological groups and Table 2.3.8(iii) summarises the data by weapon category.

Hardness of the sample should be directly related to the distortion of the grains and the extent of this is is shown by the graph in Figure 2.3.8(v). Clearly there is some correlation; indeed the correlation coefficient was 0.52 and was significant at the 1% level. However, the extent of overlap does underline the problems encountered in assessing grain distortion in the intermediate category, mentioned in Chapter 2.3.6 above, as well as the problems of heterogeneity when measuring micro-hardness.

All of the means were tested pairwise for equality using Student's t-distribution (Shennan 1988, 306). This test requires that the data form a normal distribution and measures of skewness and kurtosis for each of the groups were examined in order to ensure that they fell within a range compatible with an assumption of normality. Any case where either of these measures was not within 1.96 standard errors of zero, that is within the 95% confidence range, deviated significantly from normality. The only group to fail these tests was excluded from the statistical analysis and the data are marked with an asterisk in Table 2.3.8(ii). All differences described as significant in what follows were shown by the test to be statistically significant at the 5% significance level

The mean hardness for South Eastern weapon samples was significantly higher than for the East Anglian and the Scottish samples whether or not the samples with a burnt microstructure were included. The mean for the Western samples was also significantly higher than that for the Scottish samples but this was not the case when samples with a burnt microstructure were excluded, as may be seen in Figure 2.3.8(i).

When weapons from typological groupings were compared the Early and the Wilburton groups had mean hardness ratings significantly higher than the Ewart Park group, as illustrated in Figure 2.3.8(ii).

Restricting the analysis to swords meant that the regional differences were even more obvious with the South Eastern samples being, on average, significantly harder than each of the other regions. Restricting the analysis to spearheads showed a similar overall pattern but the South Eastern samples were only significantly harder than the Scottish samples.

The comparison of typological groupings for swords was very similar to the overall pattern with the Early and Wilburton groups being significantly harder than the Ewart Park but only the Wilburton group was significantly harder than the Ewart Park when samples with burnt microstructures were excluded. Spearheads, which also exhibited the same pattern, showed a statistically significant difference only between the Early (basal-looped) and Ewart Park spearheads and this was not significant when burnt samples were excluded.

The means for sword and spearhead samples were compared overall, see Figure 2.3.8(iii), and within each region. In all cases the mean for spearheads was lower (and the variance generally greater) than that for swords and the differences were statistically significant in all but the Western region. A comparison for each of the Wilburton and Ewart Park groups, where a similar pattern prevailed, showed statistically significant differences between spearheads and swords of the Ewart Park group in the South East and between those of the Wilburton group in East Anglia. At this level of subdivision many of the categories had too few members to allow for statistical analysis.

Regional analysis of the typological groupings for swords showed much the same patterns whether or not the burnt samples were excluded. Within the Ewart Park group, South Eastern samples were again significantly harder, on average, than in the Scottish and Western regions, as shown in Figure 2.3.8(iv). The distribution of the East Anglian Ewart Park swords could not be regarded as normal and thus they could not be deemed significantly less hard than thos from the South East. Within the Wilburton group of swords the South Eastern samples were significantly harder than the East Anglian and the same was true of the Wilburton spearheads. Among the Early spearheads the South Eastern samples were significantly harder than those from the West.

Hardness measurements showed significant differences between regions, typological groupings and weapon type. There was a decided tendency for hardness to be high in the South East and for the Ewart Park grouping to be less hard than the earlier Wilburton and Early groups. Sword edges were, unsurprisingly, harder on average than spearheads but the pattern of regional and typological differences was similar for both types of weapon.

2.4 Metallographic Examinations of Small Samples - Summary

The characteristics analysed above cover the main features visible on metallographic examination of the over 200 small, mostly edge, samples from swords and spears and show that the post casting manufacturing techniques used varied considerably but that a high proportion of the weapons had received broadly similar treatments.

Corrosion was less of a problem than anticipated in performing the examinations. The manufacturing methods used and the obviously rapid stabilisation of the surface layer after burial in most cases appears to have largely ensured that the metal was relatively sound, even after 3000 years. Except in a few examples, where corrosion has penetrated along what was clearly a severely strained microstructure, outlining grain boundaries and strain lines, most of the corrosion is at the surface, in specific areas, probably of high lead or tin concentration, and around large porosity voids.

Porosity was visible in the majority of samples although approximately 15% showed virtually none. The more severe levels of porosity tended to be less common in swords than in spearheads. Hammering will effectively close up minor levels of the inevitable casting porosity and it is apparent, both from the total absence of porosity in some samples and the distortion of the interdendritic porosity in others, that they have indeed been hammered.

Almost all of the samples contained copper sulphide inclusions and these were distorted in a manner consistent with directional deformation in the vast majority of samples, although rather more spearhead samples had totally undeformed inclusions than sword samples. The degree of deformation in the most heavily worked samples was extreme, with features which would have begun as spheroids reduced to fine 'strings' within the metal. The percentage deformation undergone by the sampled area in such cases is probably in excess of 80%, with the original rounded extreme edge having been 'stretched' out to at least 5 times its original width. Such extreme deformation was more common in swords than in spearheads.

Tin bronze is inclined to be 'hot short', that is it will tend to crack during hot working, even without the benefit of the areas of lead, liquid at 326^{o}C, and substantial sulphide inclusions, which can give rise to a liquid phase at 813^{o}C or above, so prevalent in Late Bronze Age artefacts. Thus it is clear that any hammering of the edges of the weapons was done cold and the internal stresses were removed by annealing where necessary.

Over 80% of the samples showed at least a few areas of high tin delta phase and/or the alpha plus delta eutectoid, although 35% had very little. The presence of these brittle phases could have made cold work more difficult (Northover 1988, 132) and it is clear that great care must have been taken to avoid cracking the metal. The sequence of working and annealing must, in some cases at least, have been repeated several times to achieve the deformation required.

Annealing at temperatures around 600°C will recrystallise the metal but the removal of coring and gross heterogeneity requires relatively lengthy periods of annealing at somewhat higher temperatures. Only around 15% of samples were not fully recrystallised but some 75% showed at least some signs of residual coring and 80% had some high tin phases remaining. This clearly shows that many of the samples had been annealed for very short periods of time at relatively low temperatures and that very few had been 'saturated', that is undergone long exposure to high temperatures which removed the inherent heterogeneity, while a few others had received no heat treatment at all. Spearheads were more common in this latter group than swords and early types were more likely not to have been annealed than the later typological groups.

The few samples which were not recrystallised typically had large uneven grains whose size depended solely on the speed of cooling after casting. The size of the grains in other samples depended on complex interactions between working and annealing conditions. The variability in size was generally correlated with the grain size itself, but was greatest for those samples which had been only partly recrystallised. The burnt microstructures were excessively annealed and had, as a result, very large grains but the vast majority of samples had much smaller grain sizes indicative of moderate to substantial cold working followed by a rapid, low temperature anneal. Spearhead samples tended to have rather larger grains on average than comparable sword samples, which would indicate either extra annealing or less cold work prior to annealing for spearheads and the other microstructural evidence tends to support the latter.

While the inclusions within the sample retain the effects of deformation even after annealing, the grain structure itself does not, except in the tendency for grain size on recrystallisation to be smaller, for similar annealing procedures, if the degree of cold work applied was greater. Thus it is the distortion of grains, the presence of strain lines and the presence of bent twins, in annealed structures, which reveals the extent of the final hammering. The vast majority of the samples did show some distortion of the grain structure although relatively few were very severely distorted.

The hardness of the samples exhibited a wide range of values and the extremes thereof may have been caused by readings taken on, or near to, areas of porosity, corrosion or severe damage. Within the body of the data there were definite concentrations in certain areas and the quantitative analyses indicate the complexity of the distribution rather better than the very limited categorisation of grain distortion. The complexity of the overall distribution probably reflects the regional and chronological differences observed.

The lowest readings were almost all given by those microstructures consistent with very long, high temperature annealing which were clearly visible in the weapons from hoards known to have been burnt. The hardness values which should approximately coincide with the central group of the grain distortion category included a series of peaks, in the ranges 110-140, 140-160 and 160-190, as can be seen in Figure 2.3 8(vi), showing that the central group of grain distortion might incorporate three overlapping populations. There was another decided peak at around 200HV, which probably exhibits the desired hardness for a certain range of weapons, and a small number of samples with even higher hardness readings.

The fact that spearhead samples were generally less hard and their hardness readings were more variable than swords also indicates that there was at least some level of direct control exercised over the hardness of the finished edge. Thus it seems reasonable to suppose that simply achieving the desired shape and fineness of edge was not the only aim of the weapon maker and that a fairly sophisticated appreciation of the qualities of the alloy and how to change them was within the range of at least some metalworkers.

The characteristics examined do show some statistically significant cross correlations but none of these was particularly strong except for that between coring and recrystallisation, which had already been incorporated into one characteristic. The strongest of the remaining correlations was that between grain size and coring/recrystallisation (correlation coefficient 0.54) and this was followed closely by that between hardness and grain distortion (correlation coefficient 0.52). Both of these correlations stem from the fact that the characteristics concerned result largely from the same processes. The first pair relate mainly to heat treatment and the second to mechanical deformation. It is indeed surprising that the correlations are not stronger.

Other correlations of around the same order are those between porosity and corrosion (correlation coefficient 0.48), grain size and grain distortion (correlation coefficient -0.43) and inclusion distortion and grain distortion (correlation coefficient 0.39). These are rather more complex in origin. It is likely that corrosion will penetrate porous metal rather more than sound metal but it is also possible that some of the apparent 'porosity' has resulted from corrosion processes. Grains which are undistorted tend to be those which have either been left as cast or which have been subjected to lengthy heat treatment, giving rise, in both cases, to large grains. Inclusion distortion indicates the total mechanical deformation undergone, regardless of annealing episodes while grain distortion measures only that caused by the final episode of mechanical deformation, which takes place after all annealing processes are completed.

The application of discriminant analysis, using only those variables where some statistically significant differences in distribution had been shown to exist, generally failed to produce any clear cut separation of cases either according to type or to region although restriction of the regional analysis to Ewart Park swords alone did improve the limited degree of separation achievable. Regional variations in manufacturing techniques will be discussed in Chapter 6 below. The full metallographic data are summarised in Appendix 2.

2.5 Cross Sectional Microstructures

In addition to the small samples taken during the programme and borrowed from Dr Northover, four samples of cross sections of swords were obtained for further examination. The examination of such samples can give considerable insight into the extent of the heterogeneity of the microstructures thereby shedding further light on the manufacturing processes. It must of course be borne in mind that such samples are almost invariably taken from areas where the metal has already broken and which are likely to represent the weakest points of the original artefact.

The first, which was a half section of the blade, had been cut from a broken sword from the Blackmoor (Hants) hoard which is considered to be typologically a mixture of Wilburton and Ewart Park (Colquhoun 1979) and has been dated to circa 1000BC (Needham 1997). Two others were retrieved from the Tylecote collection, now held at the British Museum. These came from swords of Ewart Park type found in the Northern Gilmonby hoard (Coggins and Tylecote 1983), and were typical metallurgist's samples encompassing, in one case, an entire cross section of the sword and in the other (Gil76) a half cross section. A further cross sectional sample from near the missing tip of an unprovenanced sword of Halstatt type from the Royal Armouries collection, which, although unprovenanced, is thought likely to have come from the Thames, was also examined.

2.5.1 Blackmoor Hoard, Sample BM20, Sword 1891 5-14 35

The entire etched cross section, at 50 times magnification, is shown in Plate 2.5.1.

The sample is only slightly corroded around the surface with some very slight intergranular penetration at the extreme outer edge. The, mainly interdendritic, porosity, which at the outer edge is virtually closed up (Rating 2), becomes much more evident from around 2mm into the blade and increases further as the centre of the blade is approached. The sulphide inclusions reveal substantial deformation (Rating 4) at the outer edge but become much less distorted as one moves towards the centre. The grains at the cutting edge are distorted with some strain lines and bent twins (Rating 3). The average of three hardness readings near the cutting edge was 163.4HV.

The cutting edge which has been worked is clearly defined by the blade profile. It shows a fully recrystallised structure, with tiny grains (grain size group a, <10 microns), twins and remnant coring (Rating 3) in the first 2mms of the blade (100mm of the photograph). The grain size gradually becomes larger as one moves in from the edge until, around 3mm in, the centre of the blade begins to show unrecrystallised areas. These areas become more extensive as one moves further in but a thin layer at the blade surface continues to show recrystallisation. At what was the centre of the blade the structure is dendritic, cored and porous. There are areas of delta and alpha plus delta eutectoid throughout the sample although they are more obvious towards the centre. The lead content is very segregated into quite large 'pools' which are visible throughout the centre of the blade, some being relatively close to the surface, but there is much less lead within the worked area of the cutting edge. This lead segregation was the subject of research at the British Museum (Hughes, Staniasek & Northover 1982)

2.5.2 Gilmonby Hoard, Sample Gil 76

The entire etched cross section, at 50 times magnification, is shown in Plate 2.5.2.

The sample is fairly corroded around the surface but there is very little penetration except at the extreme outer edge. The, mainly interdendritic, porosity, which at the outer edge is virtually closed up (Rating 2), becomes much more evident from around 3mm into the blade and is very substantial (Rating 5) in some areas at the centre of the blade. The sulphide inclusions show substantial deformation (Rating 4) at the outer edge but become much less distorted as one moves towards the centre. However the grains themselves, at the outside edge are not heavily distorted and there are few signs of strain lines or bent twins (Rating 2). Tylecote measured the hardness, using a 1kg weight, at 153HV, near the cutting edge, and 129 HV, near the centre.

The cutting edge shows clearly a fully recrystallised structure, with small grains (grain size group c, 15-20 microns), twin lines and very little remnant coring (Rating 2) in the first 2mms of the blade (100mm of the photograph). The grain size gradually becomes larger as one moves in from the edge until, around 3mm in, the centre of the blade begins to show unrecrystallised areas. These areas become more extensive as one moves further in and, by around 8mm in, even the outer surface areas are unrecrystallised. At what was the centre of the blade the structure is dendritic and cored. There are areas of delta and alpha plus delta eutectoid and of lead throughout the sample although they are more obvious towards the centre.

2.5.3 Gilmonby Hoard, Sample Gil 81

The etched cross section, including one cutting edge and the blade midrib, at 50 times magnification, is shown in Plate 2.5.3. The etch in this case is particularly light and details of the grain structure at the cutting edge are not clear from the low magnification photographs. An insert shows the cutting edge at higher magnification (200:1).

The sample is very corroded around the surface and there is some corrosion associated with porosity. The porosity at the outer edge is not completely closed up (Rating 3) and seems to be mainly interdendritic. It becomes much more evident from around 2mm and, at around 8mm in there are large round voids, indicative of gas porosity which continue through the centre of the blade. The inclusions show substantial deformation (Rating 4) at the outer edge but become much less distorted as one moves towards the centre. The grains at the cutting edge are somewhat distorted and there are some strain lines and bent twins (Rating 3). Tylecote (1983) measured the hardness, using a 1kg weight, at 132-141HV near the cutting edge and 62HV near the centre.

The cutting edge showed a fully recrystallised structure, with small grains (grain size group c, 15-20 microns), twin lines and a little remnant coring (Rating 2) in the first 2mms of the blade (100mm of the photograph). The grain size gradually becomes larger as one moves in from the edge to a distance of around 4mms. The centre of the blade is largely unrecrystallised, with large uneven grains and dendritic coring. Most of the surface has been corroded so that it is impossible to tell whether or not the outer surface areas are recrystallised. There are areas of alpha plus delta eutectoid and of lead throughout the sample which are larger and more obvious towards the centre.

2.5.4 Royal Armouries, G06

The etched cross section, including one cutting edge and the blade midrib, at 50 times magnification, is shown in Plate 2.5.4.

The sample is fairly corroded around the surface and there is some slight intergranular penetration at the extreme outer edge. The corrosion at the centre, around the most porous areas where the blade was broken, is also substantial. There is extensive gas porosity, which at the outer edge is virtually closed up (Rating 2), but becomes much more evident from around 2mm into the blade and is very substantial (Rating 5) in some areas at the centre of the blade. The sulphide inclusions show very substantial deformation (Rating 5) at the outer edge but become much less distorted as one moves towards the centre. The grains themselves, at the outside edge are fairly heavily distorted and there are strain lines and bent twins (Rating 3). This indicate that the metal was relatively hard but, since the sample was only held for a brief period, it was not possible to measure the micro-hardness directly.

The cutting edge shows clearly a fully recrystallised structure, with small to medium grains (grain size group d, 20-25 microns) and very little remnant coring (Rating 2) in the first 2mms of the blade (100mm of the photograph). The grain size gradually becomes larger as one moves in from the edge until, around 5mm in, the centre of the blade begins to show unrecrystallised areas. These areas become more extensive as one moves further in although a thin layer of surface recrystallisation (up to around 0.5mm) is present throughout. At what was the centre of the blade the unrecrystallised grain structure shows some remnant dendrites and coring. There are a only a few small areas of high tin phases and of lead throughout the sample.

2.5.5 Manufacturing Processes

The processes used to make these blades were broadly similar in that all were cast in moulds made from a similar material, most probably clay, giving rise to the large, uneven grains visible in the centres of the blades. The blade edges were hammered into shape, thinning and stretching the metal outwards to form a fine edge. This caused distortion of inclusions and of segregated lead and the closing up of porosity in the hammered areas. The hammered blades were then annealed, causing recrystallisation of the worked areas with characteristic 'annealing twin' lines, but the heating concerned was short lived and at a temperature only just sufficient to recrystallise the grains (approx. 580-600°C). Thus the original as-cast grain structure was left visible in the centre, the grains in the recrystallised areas are relatively small and some of the coring which resulted from the cooling speed of the original cast, is still visible. The annealed edges were then hammered again, giving rise to distortion of the grains, strain lines and some bent twin lines, to harden them. The differences in microstructures exhibited by the four samples are largely due to minor differences in the manufacturing processes, as described below.

The first sword edge sample, BM20, has substantial porosity in the centre, indicating that the casting process was less than perfect. It came from an area relatively close to the sword tip and appears to have been cooled rather more slowly than the others after casting, causing extreme segregation of the lead content. It was extremely heavily worked, as the distortion of inclusions and very small re-crysallised grain size attests. It is likely that this edge underwent more than one annealing episode as this level of distortion would be hard to achieve without an intermediate softening of the metal. The final hammering was relatively substantial giving rise to a fairly hard blade edge.

The second blade shows rather less porosity, except at the extreme centre where shrinkage on cooling is most likely to appear. It has a similar as-cast grain size to the first sample but, since, in this case, the sample comes from near the centre of the blade, the sword was probably cooled rather faster. Lead segregation is less evident, which is in line with faster cooling, but may indicate that the original lead content of the melt was lower. The size of the recrystallised grains at the working edge indicates that the amount of cold work applied was less than in the first case but the measured hardness indicates that the final hammering was not substantially less severe than that received by the first sword.

The third sample, Gil 81, is microstructurally very similar to the second but the morphology of the porosity indicates some problems with gas being produced during casting. The as-cast grain size seems rather smaller than in the previous two samples, which could indicate faster cooling or a greater level of impurities, which provide 'seeds' for crystallisation. The recrystallised grain structure shows a similar level of cold working and annealing to those applied to the second sample but the measured hardness, caused by the final hammering, is rather less than in that case.

The last sample, G06, is a prime example of a poor casting, with extensive gas porosity. The sample was taken from a point near the tip where the blade had broken and which may have been rather more porous than the rest of the blade. The as-cast grain size is in line with the third sample but, since the area is very near the tip it would have cooled faster than the blade centre, indicating that the actual cooling rate for the sword was probably closer to that of the second sample. The deformation of the metal is substantial but the size of the recrystallised grains at the working edge is larger than in the other samples, indicating that the annealing temperature may have been rather higher.

2.6 Composition

The compositional analysis of the samples may be divided into two parts; the trace elements, iron, cobalt, nickel, zinc, arsenic, antimony, silver, gold and sulphur, and the alloying elements, tin and lead. The former, considered in Chapter 2.6.1 below, provide clues as to the nature of the original ores smelted to produce the metal and help to identify the existence of different areas of circulation for metal, both newly smelted and recycled, during particular periods and of changes in such patterns over time (Northover 1982a). The latter, considered in Chapter 2.6.2 below, indicate the metal composition chosen by the weapon maker and may cast light on the extent to which that composition was deliberately controlled.

As a result of the design of the sampling programme, discussed in Chapter 2.1 above, a number of the weapons sampled had already had compositional analyses performed on metal from a different part of the weapon using AAS (atomic absorption spectrophotometry), although in a few of these cases EPMA was used. Comparisons between the results of these previous analyses and those of the samples used in this study are considered in Chapter 2.6.3 below.

The results of the compositional analyses for each sample are tabulated in Appendix 2.

2.6.1 Trace Elements

The major trace elements encountered were nickel, silver, antimony and arsenic. The first factor tested for statistical significance was the total of all the measured trace elements. This factor was tested in order to assess the overall levels of relative impurity of the copper used while minimising the problems caused by the variability of results for those individual trace elements which are most inclined to segregate during cooling of the cast object, discussed in Chapter 2.6.3 below. It is only valid if, as in this case, the impurity suite of trace elements is reasonably consistent as to its major constituents. The ratios of the various trace elements were then used to help define compositional groups.

2.6.1.1 Total Trace Elements

The distribution of the totals of trace elements for all samples is shown in Figure 2.6.1.1(i). The majority of samples had a total below 1% but substantial numbers had totals up to 2% and a few others were in the range from approximately 2 - 5%. One sample with a total of 22%, including 12% Sb and 6% Ni, which was in essence an antimony bronze (Northover 1982, 78) was so exceptional as to require exclusion from the analyses.

The data are summarised by typological grouping, by region and by weapon category in Tables 2.6.1.1(i)-(iii). Student's t-distribution test for equality of means requires that the data for each of the groups to be compared form a normal distribution and measures of skewness and kurtosis for each of the groups were examined in order to ensure that they fell within a range compatible with the assumption of normality. A substantial number of the groups showed either skewness, kurtosis, or both and the data were therefore subjected to a logarithmic transformation and the resulting distributions were tested. Any where the calculated measures fell outside 1.96 standard errors of zero, and thus remained incompatible with an assumption of normality, were excluded from further consideration and the data are marked with an asterisk in the relevant Tables. The means of the transformed data, in effect the geometric means of the original data, were then tested for equality using Student's t-distribution. All differences described as significant in what follows were shown by the test to be statistically significant at the 5% significance level

Figures 2.6.1.1(ii)-(iii) show the distributions of the raw data by typological grouping for all the weapons and for the South Eastern weapons alone. The geometric mean for the Wilburton group was significantly higher than for all other groups both overall and within the South East. There appears to be some possibility that the distributions within the typological groupings could be rather complex with one major and at least one minor mode. If this were the case the assumption of normality, and thus the test used, would be statistically invalid.

Figures 2.6.1.1(iv)-(v) show the distributions of the raw data by region for all the weapons and for the Ewart Park weapons alone. The regional analysis showed that the South Eastern and East Anglian samples had geometric mean values significantly higher than those from the West, which reflects the absence of Wilburton material from the Western region. However the range of values exhibited by the Scottish samples was wider than that of any other region despite the lack of Wilburton material there. When consideration was restricted to Ewart Park material only, the pattern was partially reversed with the geometric mean values in East Anglia and Scotland exceeding those from the South East and the West, although none of the differences was statistically significant. There again appeared to be a possibility that some distributions could be multi-modal.

When the geometric mean totals for swords and spears were compared there was a statistically significant difference overall with the figure for swords being substantially higher than that for spearheads. Figures 2.6.1.1(vi)-(vii) show the distributions of trace element totals by typological grouping and by region for swords and spears.

The geometric mean total figures for sword and spear samples from the Wilburton and Ewart Park typological groupings were not markedly different but the Early group showed a much lower total for spears than for swords. However the main reason for the difference between swords and spears seems to lie in the figures for the South East, where the discrepancy between the geometric mean totals was statistically significant. The large Ewart Park group of South Eastern weapons showed little difference in geometric mean total between spears and swords but among the Early group of South Eastern weapons the discrepancy was again statistically significant.

Further investigation of the potential for identification of regional or chronological separation of metal supplies required a division of the samples into compositional groupings defined by their trace element profiles.

2.6.1.2 Compositional Groups

The grouping criteria used to determine the compositional groups were based on the four major trace elements, nickel, arsenic, antimony and silver. Cluster analysis of the data for the weapon samples, using the percentages of these four elements as clustering variables, failed to produce any useful subdivision of the data, as the bulk of the cases fell into one large cluster. Discriminant analysis, using the same variables, produced some separation of the data according to the regional origin and rather more separation according to the typological grouping of the weapons but, in both cases, separation of the groups was far from complete and the functions concerned had no obvious explanatory potential.

The approach used was chosen in order to utilise results from previous work (Northover 1980, 231-232. 1988, 133-140. 1990, 87), discussed in Chapter 1.5 above, without incorporating the data for samples from other artefacts, on which that work was based, into the weapons database. The first publication (Northover 1980) set out compositional groups for Welsh bronze artefacts from all periods of the Bronze Age. The second (Northover 1988) dealt in particular with the composition of swords. The third (Northover 1990) dealt with one particular South Eastern Late Bronze Age group of artefacts, the Petters hoard, which included broken weapons, axes and tools as well as casting waste. A recent publication (Cowie et al. 1998) details the compositional groups of the St Andrews hoard, which included weapons, tools and ornaments and sets them in the context of major Late Bronze Age Scottish hoards. It was clear from all of these publications that the ratio of arsenic to antimony was important as was the overall level of trace elements. Graphs of the trace elements also indicated that there were regional differences in the levels of nickel and silver.

The definitions commenced with a simple grouping according to which of the dominant trace elements were present. Then the major groupings, with all four elements present, were subdivided with respect to the ratios of arsenic to antimony and of nickel and silver to arsenic and antimony. The only element of absolute measure taken into account was the level of nickel, which was used, in conjunction with the nickel to silver ratio, to subdivide the three largest groupings previously defined. The resultant groups were then examined to see which could be combined without loss of relevance to the typological and regional groupings of the samples. Although the number of groups at the end of this process was rather larger than was ideal, the loss of either regional or chronological detail caused by further amalgamation seemed excessive relative to the greater ease of data manipulation.

The resulting groupings are defined below:

Group 1: Arsenic greatly exceeds other trace elements.

$As > 4Ni$

$As > 3Sb$

$As > 4Ag$

Group 2: Arsenic and nickel principal trace elements

$As < 4Ni$

$As > 3Sb$

$As > 4Ag$

Group 3: Nickel, arsenic, antimony and silver present

$(As+Sb)>3(Ni+Ag)$

$Ni>0.2$ or $Ni/Ag>1$

Group 4: Nickel, arsenic. antimony and silver present

$(As+Sb)<3(Ni+Ag)$

$Ni>0.2$ or $Ni/Ag>1$

$0.67<As/Sb$

Group 5: Nickel, antimony and silver present. Arsenic usually present

$(As+Sb)<3(Ni+Ag)$

$Ni>0.2$ or $Ni/Ag>1$

$As/Sb<0.67$

Group 6: Nickel, arsenic, antimony and silver present

$(As+Sb)>3(Ni+Ag)$

$Ni<0.2$ and $Ni/Ag<1$

Group 7: Nickel, arsenic. antimony and silver present

$(As+Sb)<3(Ni+Ag)$

$Ni<0.2$ and $Ni/Ag<1$

$0.67<As/Sb$

Group 8: Nickel, antimony and silver present. Arsenic usually present

$(As+Sb)<3(Ni+Ag)$

$Ni<0.2$ and $Ni/Ag<1$

$As/Sb<0.67$

Group 9: Principal elements nickel, arsenic and antimony. Silver usually absent.

$4Ag<\min(Ni, As, Sb)$

Group 10: Composite group with principal elements nickel and/or silver

total trace elements < 0.5%

The distributions of the samples among the compositional groups by typological grouping, by region and by weapon category are set out in Table 2.6.1.2(i)-(ii).

The numbers in some groups were too low for statistical analyses to be performed but, by combining different compositional groups, with some common characteristics, the significance of the differences in distribution of certain characteristics could be tested using the Chi-squared distribution with a 5% significance level. The Chi-squared statistics for those tests where numbers differed significantly from those expected are set out in Appendix 1. The use of the word significant in the discussion which follows should be taken to mean statistically significant in all cases.

Figures 2.6.1.2(i)-(ii) show the distribution of samples among the compositional groups by typological grouping for all weapons and for South Eastern weapons alone. The proportions of samples from Early weapons in Group 2 and in Groups 1 and 2 combined was significantly high as were the proportions of Wilburton samples in Group 3 and Groups 3 and 4 combined.

Although Ewart Park samples were only significantly disproportionately high in Groups 5, 7, 8, 9 and 10 combined rather than in any one group, it was clear that this was generally tied to the tendency of the groups concerned to have a relatively low level of trace elements in total but to have all, or all bar one, of the four main trace elements present.

When the data for the South East were analysed separately, the pattern of significant differences was similar as far as the Wilburton samples were concerned but the bulk of the discrepancy from the expected proportions of Ewart Park samples lay only in the high numbers contained in Groups 5 and 9.

Figures 2.6.1.2(iii)-(iv) show the distribution of samples among the compositional groups by region for all weapons and for Ewart Park weapons alone. The high proportions of Scottish samples falling into Group 7 and Groups 6, 7 and 8 combined are statistically significant as is the high proportion of South Eastern samples in Groups 3 and 4 combined.

The deficiency of South Eastern Ewart Park samples in Groups 7 and 8 is also statistically significant. The Scottish samples within the Ewart Park type had a significantly high proportion in Groups 6, 7 and 8 combined, i.e. those with low nickel and a silver content in excess of nickel, and this was almost solely at the expense of Group 9, in which silver was virtually absent. The relative lack of overall Scottish representation in the higher nickel and/or high nickel to silver ratio groups (Groups 3, 4 and 5), is, however, eradicated when Ewart Park samples alone are considered.

Most notable was the very high proportion of Western Ewart Park samples (50%) contained in Group 9, although the number of Western samples was relatively small, thus precluding testing for statistical significance. This compositional grouping contained not only all of the Western swords but a very large proportion of it (40%) was made up by samples from the Blackmoor hoard, which came from the Western edge of the South Eastern region. The majority of the Western spearheads sampled came from the Early group and exhibited a composition closer to typical Middle Bronze Age types.

The only really obvious difference in distribution between spears and swords among compositional groups was the complete split in the South Eastern Early weapons with all the spear samples falling into Groups 1 and 2 and the sword samples being spread over Groups 3 to 7.

2.6.1.3 Trace Elements - Summary

The trace element pattern is clearly the result of the complex interactions of changing ore sources, mixing of metal from different sources and of recycling but, as mentioned in Chapter 1.5 above, this does not preclude its use, especially in conjunction with other information, in helping to classify artefacts typologically or chronologically, in identifying regional zones of metal circulation (Northover 1982b), in indicating artefacts potentially cast from the same melt, and eliminating that possibility for others, and in eliminating some potential candidates for the original ore source from which the metal was smelted.

Although the numbers concerned are relatively small the regional nature of the Western weapons' trace element composition, with its lack of silver content, is striking. The low nickel and relatively high silver content of Scottish samples also seems to be a largely regional phenomenon.

Clearly the Wilburton grouping includes a high proportion of artefacts made from metal containing high levels of trace elements. The same is, to a lesser extent, true of South Eastern Early swords and of Scottish and East Anglian Ewart Park weapons, relative to those from other regions.

The effects of such metal will show in subsequent products to the extent that it is recycled and mixed with low impurity metal from other sources. In addition the trace element total in recycled metal will decrease due to oxidation of more reactive elements and the lower proportion of more volatile elements remaining after each re-melt. This will be particularly obvious for arsenic which sublimes at 615°C. Losses of arsenic and antimony can be reduced to around 10% over a series of melts if the crucible is covered (Northover - pers. comm.) but it seems unlikely that efforts to do so would have been made. The very high proportions of Ewart Park weapons in the two groups containing relatively low levels of arsenic combined with the other three major trace elements could be seen as a largely chronological effect brought about by recycling relatively impure metal, thereby eroding the proportion of volatile arsenic.

The metal used in Scottish Ewart Park weapons does seem to include the range of relative impurity seen in the Wilburton weapons from East Anglia and the South East as well as the lower impurity levels seen among the South Eastern Ewart Park weapons, although the numbers exhibiting this range are relatively low when compared with the percentage of total weapons from the South East which are of Wilburton type. This could support the view that the Ewart Park weapons in Scotland encompass a longer time span than in the South East with the earliest Scottish Ewart Park weapons containing a relatively high proportion of trace elements.

If the metal used within the Wilburton tradition is seen as intrusive relative to the Middle Bronze Age pattern of trace element composition, its presence within pre-Wilburton types of swords in the South East but not within other Early artefacts must be seen as creating at least the possibility that some of these were not necessarily of local manufacture. The spearheads classified as Early were basal-looped and the fact that they appear to exhibit metal more typical of the Middle Bronze Age could, however, indicate that the weapons sampled do actually pre-date even the Early swords from the South East.

2.6.2 Alloying Elements

It is evident from the proportions found in the alloy that both tin, with a mean of around 10%, and lead, with a mode around 1%, were deliberately added to copper to improve certain properties of the metal. These properties were mainly related to the mechanical properties of the weapon in the case of tin and the viscosity of the melt in the case of lead.

2.6.2.1 Tin

The overwhelming majority of metal artefacts made during the period were composed of the copper and tin alloy to which the Bronze Age owes its name. The mechanical properties of the alloy, in particular the degree to which it becomes hard when hammered, is due to the effects of introducing a significant proportion of tin. Tin is not so commonly found as copper and sources are limited to relatively small geographic regions, the only British source being deposits in the highlands of Cornwall and Devon (Rohl 995, 59). It is widely assumed that this resource, which was certainly exploited during Roman times, was used during the Bronze Age. Thus the percentages of tin used in British artefacts may reflect the relative availability of the element and hence a relative lack of constraint in choice of alloying proportions. However, the extent to which bronze, already alloyed, was brought in to the lowland zones of Southern and Eastern Britain from the continent (Northover 1988, 130) and recycled may have acted as a constraint.

The distribution of the percentages of tin in the samples overall is shown Figure 2.6.2.1(i). The data are summarised by typological grouping, by region and by weapon category in Table 2.6 2.1(i)-(iii). Student's t-distribution with 5% significance level was used to test for differences in the means of the tin percentages. This test requires that the data for each of the groups to be compared form a normal distribution and measures of skewness and kurtosis for each of the groups were examined in order to ensure that they fell within a range compatible with the assumption of normality. Only one group, the Wilburton spearheads, showed measures incompatible with an assumption of normality and was therefore excluded from further consideration. The data are marked with an asterisk in the Table 2.6.2.1(i). All differences described as significant in what follows were shown by the test to be statistically significant at the 5% significance level.

Figures 2.6.2.1(ii)-(iii) show the tin contents for each typological grouping for all the weapons and for South Eastern weapons only. If the underlying distributions are assumed to be normal, the mean tin content of both the Early and the Ewart Park weapons are statistically significantly higher than that of the Wilburton weapons. The spread of the tin contents, as measured by the standard deviation, is widest for the Early weapons and narrowest for the Wilburton grouping. Within each region the pattern was similar but only the difference between the Wilburton and Ewart Park groupings in the South East proved to be statistically significant.

Figures 2.6.2.1(iv)-(v) show the tin contents for each region for all the weapons and for Ewart Park weapons only. The West had the highest and the South East the lowest mean tin percentages but differences in mean tin content for the regional groupings were not statistically significant. The spread of tin contents was high in the South East and in the West. Within the Early grouping the Western and East Anglian samples had relatively high tin contents and in the Ewart Park grouping East Anglia showed the highest tin content but none of the regional differences within typological groupings was statistically significant.

Figures 2.6.2.1(vi)-(vii) show the distributions of tin content by typological grouping and by region for swords and spears. The only statistically significant difference in tin content between swords and spearheads was within the Early grouping in the West where the mean percentage for the 4 spearheads (9%) was significantly lower than the 13% derived from the 4 sword samples.

2.6.2.2 Lead

The addition of lead in relatively low quantity (up tp 10%) to bronze facilitates the filling of moulds which are narrow or complex without necessarily affecting the mechanical properties of the alloy (Staniasek and Northover 1982, 265). However lead is virtually insoluble in bronze and this, combined with its low freezing point, means that there are dangers of gross segregation taking place, especially under slow cooling of the cast, which can considerably weaken the object.

There is evidence that lead addition did occur, albeit briefly, at the start of the Middle Bronze Age (Northover 1988, 135) but then ceased. Low level lead additions occur in North West France in artefacts contemporary with the Early weapons considered here (Northover 1988, 136) and in some of the Early types of British swords but the addition of significant quantities of lead to bronze is largely a phenomenon which first appeared widely in Britain in Wilburton material (Brown and Blin-Stoyle 1959). The lead in most Wilburton bronzes appears, from the results of lead isotope analysis, to have come from a single source, probably in the Mendips, and that in Ewart Park material from only a small number of sources, including the Mendips and possibly the Bristol region or the Southern Pennines (Rohl 1995, 170-1).

The distribution of the percentages of lead in in the samples is shown in Figure 2.6.2.2(i). The most striking features are the concentration of the samples in the very low (<1.5%)

lead levels, the very wide range of measured values and the very few exceptionally high cases, which obviously increase the mean value to a level considerably in excess of the mode. The problem of segregation is important in this context and will be discussed further in Chapter 2.6.3 below.

The data are summarised by typological grouping, by region and by weapon category in Table 2.6 2.2(i)-(iii). Student's t-distribution with 5% significance level was used to test for differences in the means of the total percentages. This test requires that the data for each of the groups to be compared form a normal distribution and measures of skewness and kurtosis for each of the groups were examined in order to ensure that they fell within a range compatible with the assumption of normality. A substantial number of the groups showed either skewness, kurtosis, or both and the data were therefore subjected to a logarithmic transformation and the resulting distributions were tested. Any where the calculated measures fell outside 1.96 standard errors of zero, and thus remained incompatible with an assumption of normality, were excluded from further consideration and the data are marked with an asterisk in the relevant Tables. The means of the transformed data, in effect the geometric means of the original data, were then tested for equality. All differences described as significant in what follows were shown by the test to be statistically significant at the 5% significance level

Figures 2.6.2.2(ii)-(iii) show the lead content according to the typological grouping for all weapons and for the South Eastern weapons alone. Although the number of Early samples is small the obviously low lead level in the Early group is statistically significant in terms of the geometric mean value when compared with the Ewart Park group. Statistical testing of differences with the Wilburton and Late groups was ruled out by the failure to meet normality criteria. When consideration is restricted to the South East the Early group's geometric mean lead content is significantly lower than that of the Ewart Park group and when restricted to East Anglia it is significantly lower than that of the Wilburton group. Within the West the significance of the Early weapons' low mean lead content could not be tested. The numbers of samples concerned is small and the difference is exaggerated by one of the very high lead level samples mentioned above.

Figures 2.6.2.2(iv)-(v) show the lead content by region for all weapons and for the Ewart Park group only. Although the mean lead contents did differ with the East Anglian samples giving relatively low values, the differences were not statistically significant. When attention was restricted to the Ewart Park samples the East Anglian geometric mean lead content was statistically significantly lower than those of the Scottish and South Eastern groups and the Scottish geometric mean value was actually substantially, though not statistically significantly, higher than that derived from the South Eastern samples. The distribution of mean lead values for the Scottish Ewart Park samples did exhibit signs that multi-modality was a possibility, although there was considerable concentration within the very low values.

Figures 2.6.2.2(vi)-(vii) show the lead content according to category of weapon by typological grouping and by region for all samples. The obvious difference within typological groupings is in the Early group where spear samples show very low lead values but the sword samples include some higher levels of lead. The difference in geometric means was statistically significant within the South East and the West for the Early weapons. None of the regions exhibited statistically significant differences between the geometric mean lead contents of spears and swords overall.

2.6.2.3 Alloying Elements - Summary

The variations in tin content do not seem to be regionally biased except to the extent that the Wilburton typological grouping, with its lower mean and narrower range of tin content, is itself a Southern and Eastern phenomenon. However the difference between the Wilburton and Ewart Park tin contents also is significant within the South East. This would support the view that the metal supply commonly used for the manufacture of Wilburton weapons may have been more constrained in its range of tin content than any of the others considered.

Lead content in weapons also appears to be more closely related to typological grouping than to regional variation. While the introduction of lead, to assist casting, seems to have largely arisen with the introduction of swords and to have happened on both sides of the Channel, the heavier additions made during the manufacture of Wilburton weapons appear to have tailed off and their results been diluted by mixing with unleaded metal during subsequent recycling. It is possible that the problems in metal performance caused by gross lead segregation may have been recognised as being associated with high lead levels and the working practices may have been changed as a result but it may simply have been the result of the demise of those weapon makers who were wedded to the use of high lead alloys. In the South East this chronological sequence is clear but this means that the lead content of some Scottish Ewart Park weapons appears anomalously high when compared with other regions.

Tin content within the alloy was at levels which provided ample scope for edge hardening throughout the period, although it is interesting to note that higher levels were used in Western swords than in spearheads in the period when swords were first introduced. The only real differential in use of lead between swords and spears also lies in the period when swords were introduced and it was in swords that the lead was first used. Since a small addition of lead would have assisted in the casting of complex spearheads just as much as in sword casting it should not be surprising if, once the practice was introduced, there was no real difference in its use between spears and swords.

2.6.3 Compositional Comparisons

The opportunity to compare results of compositional analysis on metal from different areas of the same object arose as a result of the requirement to take metallographic samples from undamaged edges of weapons. Some of the objects had already been analysed in previous studies by AAS using drillings from the body of the weapon and these results, which were provided by the British Museum, could be compared with those from the solid samples measured using EPMA. In addition there were three swords for which solid samples from damaged areas or hilts had previously been taken and one broken spearhead, the two parts of which had become accidentally separated over thirty years ago, which was unwittingly sampled twice before the pieces were reunited.

It must be emphasised that the comparisons given here do not seek to compare different methods of compositional analysis, a subject recently covered in considerable detail elsewhere (Northover & Rychner 1998), but do give an indication of the considerable caution which must be used when discussing the results of compositional analyses for individual prehistoric bronze artefacts. There are some well known problems caused by micro-segregation of certain elements, when analysing the very small volumes of metal at several points of a solid hetergeneous sample, as happens with methods such as EPMA, which are much less important with other methods where a more substantial quantity of metal is effectively homogenised and analysed, as is the case with the drillings used in AAS. It is clear from the results which follow that, in addition to the differential effects of micro-segregation on results using different analytical methods, sampling from different areas of the same weapon can give very dissimilar results.

In theory, if the metal is homogeneous, the readings, from each of the two samples, for each element should be the same. Northover & Rychner (1998) have shown that different methods may not produce identical results but that there is usually a linear relationship sufficiently strong to enable calculation of a correction factor. Thus, even for elements not likely to be subject to segregation, the graph of the two readings for each weapon may not exhibit a 45 degree slope. However, there should be a linear relationship, whose strength can be measured by the correlation coefficient, for most elements.

Figures 2.6.3(i)-(vi) show graphically the results for the six main elements where sufficient pairs of readings existed. All of the correlation coefficients listed below were statistically significant at the 1% level except for those for arsenic and cobalt, which were significant at the 5% level. In some cases the elements concerned were present only in such very low concentrations that the analytical methods used were close to their detection limits and the accuracy of some of the lowest measurements may be questionable. This factor had considerable effect on the results for iron, zinc and bismuth, where the correlation coefficients were not statistically significant.

Element	Coefficient of Correlation
Lead	0.7091
Tin	0.7690
Silver	0.8632
Nickel	0.7435
Arsenic	0.5240
Antimony	0.7293
Cobalt	0.5752

Clearly, even elements generally present in somewhat higher concentrations gave readings which, although correlated, differed considerably.

The lead and arsenic results, may have been affected by the difference in analytical methods used, and possibly by diminution of surface lead during sample preparation as mentioned in Chapter 2.2 above, but the difference due to sample site is clear from Figure 2.6.3(i), which shows the lead figures with the low readings coming consistently from the samples situated at the cutting edge. The opposite effect may have been present, to a lesser extent, in the readings for tin, which does have a tendency to 'sweat' leading to enhanced surface levels (Bailey 1960, 389).

It is virtually certain that ancient bronzes will show at least some degree of segregation, either micro-segregation, giving rise to coring, or macro-segregation, i.e. the concentration of insoluble impurities and constituents towards the centre of the casting (normal) segregation or the outside of the casting (inverse segregation). There also exists a possibility of gravitational segregation, particularly under slow cooling conditions, where densities differ substantially (Bailey 1960, 389-391). Evidence for this latter has been shown by analysing samples taken from intervals along the length of long artefacts cast in the Late Bronze Age. Five leaded bronze swords were sampled in this manner and four of these showed signs of gravitational segregation of lead (Craddock 1980). Combining such factors with the low levels of trace elements and the very small areas analysed by some methods is bound to give rise to differences in compositional analyses, although the extent of those differences clearly depends on the element concerned.

Obviously it is therefore unwise to assume that an analysis from one area of any particular artefact will represent the composition of the entire object. Again, the use of a large number of samples from one object would be required to ascertain the composition of the metal which was cast. Similarly, single samples from a large number of objects cast from the same, or similar metal, possibly adjusted for any known directional bias due to sample positioning, should, when compositional data are analysed statistically, indicate the composition of that metal.

3 Experimental Replication of Edge Damage

In order to replicate use damage on sword edges it was first necessary to produce blade edges whose shape, composition, microstructure and hardness resembled those of Bronze Age swords.

3.1 Experimental Blade Manufacture

In a previous experimental casting, wooden sword sections, around 150mm long, 37mm wide and 7mm maximum depth (rectangular in plan and lenticular in cross section) were used as the pattern for sand casting in order to ascertain whether lead was differentially segregated away from the edges when cast in this medium. A melt of 10% tin, 80% copper and 10% lead (by weight) and another of 10% tin 85% copper and 5% lead were used. On metallographic examination of sections across the middle of each cast, the lead appeared to be evenly dispersed throughout the casting. A further series of experimental castings in sand, of leaded bronze bars with a rectangular cross section, gave very similar results (Welham 1997). Castings in metal, stone and clay moulds, of a variety of leaded bronze bars with a circular cross section, showed that lead was fairly evenly dispersed in all but the high lead bars cast in clay, in which the lead formed large irregularly shaped 'pools' due to the slowness of heat transfer from the molten metal to the mould (Staniaszek & Northover 1982, 263).

Although the original two high lead sword sections were cast successfully in sand it was felt that a closer approximation to the microstructures produced by casting in clay, for which we have ample British Late Bronze Age evidence, would be produced by investment casting, where the mould is built up by a series of coatings applied to the model, which may then be removed when the shell hardens, if the shape permits, or burnt out if the shape is too complex. The decision to use a professional casting company ensured that a sufficient number of successful castings could be produced in the limited time available. The material used to produce the investment shell was an approximately 50:50 mixture of Crystacal Casting Plaster and Fine Casting Plaster with a small amount of W75 Silica Sand. A wooden pattern was again used but, in order to provide for mounting on a test machine, the pattern consisted of a similar, but slightly smaller section of sword blade (36mm wide, 220mm long and 6mm maximum thickness), cut in half longitudinally and attached to a strip of wood 4mm thick, 18mm wide and 220 mm long, as shown, to scale, in Plate 3.1(i).

The alloy used for the casting of Late Bronze Age swords in Britain was, in broad terms, relatively constant with a tin content of around ten per cent and a fairly low lead content, as shown in Chapter 2.6.2 above. It was decided to use an alloy with low levels of trace elements, in keeping with many of the swords analysed, as shown in Chapter 2.6.1 above, and, to that end, a standard alloy, specification GB CU SN 10 DIN 17656/1973 was purchased. The composition of the alloy is shown in the Certificate of Analysis, reproduced in Figure 3.1(i).

The most variable component in the analysed samples was the lead, the mean value obtained from the analyses was 2.6% but this was affected by a few samples which gave very high lead readings. It was decided to aim to achieve an alloy with around the median value (0.9%) but to allow for the greater volatility of lead and for the likelihood that some differential segregation might occur 100grams of lead was added to the melt of 10kgs of the alloy giving, in theory, a tin content of 9.7%, a lead content of 1.3% and 88.6% copper. The aim was to replicate the composition of a typical sword edge only and not that of an entire sword.

Several samples, which were taken from the experimental sections for metallographic examination, were subsequently analysed for chemical composition using EPMA. The results of this, reproduced in Figure 3.1(ii), were rather different from the expected composition. The average value for tin was 10.98%, the average for lead was 0.28% and the average for arsenic was 0.45%. Clearly there has been some effect due to inhomogeneity and to the position, on the cutting edge, from which the samples were taken, with the similar results to those detailed in Chapter 2.6.3 above. The tin level is higher and the lead much lower than expected. The arsenic readings are highly variable and around two thirds show the negligible levels which would be expected from the Certificate of Analysis. It is possible that the samples were contaminated during preparation and that this gave rise to a few high readings (Northover - pers. comm.). Such variations in composition would have had no effect whatever on the mechanical properties of the metal (Northover - pers. comm.).

Seven of the sword sections were cast. Several of the sections had what appeared to be a shrinkage cavity, in two cases (#1 and #7) very clearly visible to the naked eye, near the backing strip at one end, as shown in Plate 3.1(ii). X-ray exposures showed that the castings were otherwise sound, except for one (#5) which showed a small cavity approximately one third of the way along the section about 10mm back from the edge.

The sections were fettled by the founders before delivery. A section, as delivered, is shown in Plate 3.1(iii)

Although a sharp edge could be produced by simple grinding of the castings as delivered, this would not reproduce either the hardness or the microstructure seen in the archaeological samples. It appears that the procedure most likely to have been used was hammering, with intermittent short low temperature annealings (Northover - pers. comm.). As a complete novice in the art of smithing could not hope to produce an adequate result, the services of Robert ('Helgi') Seaton, an expert in the reproduction and use of historical weapons and armour, were enlisted, as may be seen in Plate 3.1(iv)

3.1.1 Edge Finishing - First Session: Sword Section 1.

The session was used as a trial of the equipment and methods since Helgi's experience was mainly in hot forging of iron weapons and the techniques and tools had to be adapted to suit cold hammering of bronze. The techniques are very different. Iron is forged within a very limited temperature range, clearly visible as a result of the metal being red hot, during which the metal 'flows' and feels like a liquid under hammering (Robert Seaton - pers. comm.). Once the temperature falls below this range the metal ceases to 'flow' and it must be re-heated before further forging is attempted. This made it difficult to establish any 'feel' for the way the bronze deformed under cold hammering as the metal deformed much less dramatically and, even in its as cast state, felt relatively very hard when first being hammered. As a result of these problems and a series of violent thunderstorms, only one of the sections cast was 'edged'.

The first problem encountered was that the shape of the castings, with their T section, made too steep an angle with the face of the standard large anvil. In the end a small anvil was attacked with an an angle grinder until it was sufficiently narrow to accommodate the section. It can be seen attached to the large anvil, as modified, in Plate 3.1.1(i). The blade edge was hammered with several different square headed steel hammers varying in weight between 0.7 and 2kgs.

Once hit correctly the metal proved, to an expert, quite workable in the as cast state and a section was hammered out so that it projected by approximately 2mms beyond the original line of the casting edge. This reduced the average thickness of the hammered edge by about 40%. At this stage the metal had become harder to work and it was suspected that some hairline cracking along the outer edge was beginning. Only one possible crack was seen running backward from the edge, and this later proved to be superficial.

The worked end of the metal was then placed among the charcoal in a brazier and the temperature was measured with a thermocouple. Once the metal within the brazier had reached 550^{o}C, it was noted that the surface had turned a 'gunmetal grey' with some hints of peacock blue in the oxidation layer. After air cooling it worked more easily than before and a further 20 to 30% reduction was possible.

A further portion was hammered, as before, annealed, quenched in water and further hammered with no distinguishable difference in workability from that exhibited by the air cooled section. The thermocouple had by then ceased to function properly due to the combined effects of a loose connection and a torrential downpour and, thereafter, the attempt was made to judge temperature by colour of the oxidation layer alone.

It had been hoped that the sequence of oxidation colours noted in the measured annealing could be used as a temperature guide but this proved impractical because, as later became obvious, the 'gunmetal grey' colour was reached before the metal was annealed, any subsequent colour changes were invisible in sunlight and, in order to ensure even surface annealing, it is necessary effectively to bury the section in the charcoal.

It seems highly likely that the sword makers in the Late Bronze Age used experience to assess the adequacy of the temperature attained in a furnace, fire or brazier, probably to the extent of building a particular size and shape of annealing environment and selecting the fuel carefully in advance of the particular operation, and that direct observation of the metal during annealing played no part. Alternatively they may have relied solely on the 'feel' of the metal and re-annealed if the metal still felt too hard when working resumed.

The hammering technique which seemed to give the best results proved to be alternating between a flat blow and a blow which 'scooped' forward towards the edge of the blade and the (curved) edge of the anvil. The section was turned fairly frequently during hammering and the impression of the anvil surface quite rapidly eradicated most of the hammer marks on the reverse side. As hammering progressed signs of a slight 'bevel' line started to show on the reverse surface of the blade where it had been held at a constant angle to the anvil. This proved very difficult since the blade tended to slip backwards from the anvil edge on being hit and was difficult to hold. The cumulative shock to my hands, wrists and elbows proved extremely painful after around a dozen hammer blows and even Helgi reported some pain after the session.

After a further period of hammering the entire section was placed in the brazier until the surface turned gunmetal grey, left there for five minutes and then quenched in water. Given the limited time available Helgi finished hammering the section so that the blade expansion was approximately even along the length of the section.

It was during this process that another major problem associated with the design of the section became clear. Since there was no opposed edge to be hammered the section started to bow quite markedly, as shown in Plate 3.1.1(ii). Fortunately the T cross section is extremely strong and stood up to substantial deformation. There was moreover some benefit in using the symmetry of the bowing along the length of the backing strip to assess how consistent the working along the edge had been.

The bowing of a symmetrical blade when hammered along one edge is of course automatically removed when the other edge is hammered to an equal deformation and this would enable the sword maker to ensure consistency in the edge quality. Although hammering of alternate sides is feasible it is less time consuming and easier to monitor accuracy if the sword maker permits some bowing while hammering the length of one edge, ensuring that the bowing is even, and eliminates it by hammering the length of the other side.

Once the hammering was completed the edge was ground on a vertically mounted, foot operated, rotating wet sandstone wheel, shown in Plate 3.1.1(iii). This removed all the unevenness at the extreme edge, produced a marked and even bevel and put small parallel striations, perpendicular to the edge, between the edge and the bevel. Such marks were not compatible with those visible on the vast majority of museum specimens viewed and it is concluded that these were ground lengthwise by hand, giving scratches broadly parallel or at a very slight angle to the edge.

The result of these operations was a thin, sharp edge which could cut as easily as a used, but far from blunt, Stanley knife. In order to compare the microstructure of the blade thus produced with those from archaeological samples, a small edge sample, comparable with those taken from museum swords, was taken and prepared for examination in the same manner as those museum samples, described in Chapter 2.2 above.

A small piece (approx 40mm long) of double edged sword section, left from earlier high lead castings, was hammered on one edge, without annealing, for comparison. It proved much easier to deform than the low lead sections and the deformation achieved, as shown in Plate 3.1.1(iv), with a brief (circa 5 minute) hammering and no annealing was equivalent to that achieved on the 220mm section over a period of around two hours, including two short but, as the subsequent metallographic examination showed, not entirely effective annealings.

The sample from the end which was worked and annealed to 550^{o}C (before the demise of the thermocouple), when etched in acidified potassium dichromate, showed a 'striated' structure with bands of heavily deformed small twinned and slipped grains, as shown in Plate 3.1.1(v). The metal was not homogenised and areas of tin rich delta and alpha plus delta eutectoid were visible. Another section showed a similar structure but a section from an area subjected to only one, unmeasured, annealing showed a severely worked 'as cast' structure with much slipping but no recrystallisation, as shown in Plate 3.1.1(vi)-(vii). A sample cut from the unworked section is shown for comparison in Plates 3.1.1(viii)-(ix).

3.1.2 Edge Finishing - Second Session: Sword Sections 2, 3 and 4.

The second session took place in bright sunshine with a fully functional thermocouple.

Section 2 was hammered, with the large square sectioned steel hammer, until the edge was extended by approximately 2mm, with a decrease in thickness of 40-50% around 2mm in from the edge. This section was hammered closer to the edge than the first, mainly due to Helgi's increasing familiarity with the material leading to greater accuracy. This increased accuracy also led to a decrease in the extent of hammer impact marks on the blade since, when hit square on, no mark was made. However the deterioration of the anvil surface meant that marking of the lower surface became much worse. The blade was hammered along its full length and the relatively even resulting edge indicated that the 'stretching' was uniform.

The section was annealed in a small charcoal brazier as before. The metal temperature, as measured by the thermocouple held against the blade edge, reached 500^{o}C but bellows had to be applied before any higher temperature was obtained. The use of a larger and deeper brazier would probably have precluded the necessity to apply bellows.

The temperature was raised to around 610°C for approximately one minute and the section was then quenched in the water tank.

When the section was hammered again after annealing cracks both at the edge and towards the back, beyond the area of impact, appeared quite rapidly. The largest is shown in Plate 3.2.1(i)-(ii). It was decided to mask off the cracked area and to use the small hammer to work a small area to see how much further working could be done. The area was worked without further cracking and the rest of the edge, excluding the cracked part, was similarly worked using the small hammer.

The fact that the cracking appeared so rapidly and that it appeared in areas not being directly hammered led to the conclusion that the problem was due to 'fire cracking', an effect of the annealing conditions, in particular the temperature, rather than the working of the edge *per se*. Similar, more acute, breakages appeared in swords being made experimentally in Ireland (O'Faolain 1997: 190-191) which had been annealed in a gas hearth to 'dull-red heat' (i.e. in excess of 600°C) for around 60 seconds.

Section 3 was hammered using the small steel hammer until the edge was extended by approximately 1.5mm. This was then brought up to a surface temperature of 550°C in the charcoal brazier, using bellows from 400°C onwards, and removed immediately in order to prevent any fire cracking.

Further working on the section, after air cooling, was done with the small hammer. This produced a much more even edge than on the two previous sections, with slightly less curvature of the spine of the T section due to the fact that the small hammer was more accurate and enabled working to be confined to the outer edge. Some suspected cracks did appear towards the spine but these are likely to have been due to some minor faults in the casting in this area. There was no sign of cracking towards the edge.

The initial hammering of section 4 was done with a large (1.25 kilo) double headed copper hammer. This produced no hammer marks on the surface and, once started, the edge seemed to 'move' more easily than with the steel hammer. The iron anvil had however deteriorated markedly while the steel hammers were used and the edge of it had to be reground with an angle grinder to prevent further severe marking of the underside of the blade, one end of which had already been damaged.

The copper hammer distorted progressively, as shown in Plate 3.1.2(iii)-(iv), and there was clear work hardening of its surface which became brittle and shed small splinters during hammering. Helgi constantly changed the angle at which the blade was held in order to eliminate the resultant hammer marks and the surface finish, of all but the anvil damaged area, was considerably smoother than the previous sections.

Section 4 was annealed as before to 560^{o}C, removed rapidly and air cooled. It was further hammered, to give an overall deformation of approximately 70%.

The sections hammered during the session were then ground on the wet sandstone, foot operated wheel and buffed on an electric polishing wheel which showed up the cracks on the edge of section 2 much more clearly.

A sample from section two was later examined metallographically and proved to have recrystallised, with very small, distorted grains being visible although the metal was not homogenised, as shown in Plate 3.1.2(v)-(vi). There were some cracks clearly visible at the edge of the metallographic sample, which had itself cracked away from one edge of a two centimetre long piece, while it was being cut from the main section using a low speed diamond edged circular saw. The cracking was clearly not confined wholly to the area in which it was superficially visible.

When metallographic samples were cut from the centres of sections 3 and 4 it was clear that the 'annealing' had not been sufficient to recrystallise the metal. The grains were large and uneven but there was some distortion of the dendritic structure and heavy slip banding showing a severely cold worked unhomogenised edge, similar to that shown in Plate 3.1.1(vi)-(vii).

3.1.3 Edge Finishing - Third Session: Sword Sections 5 and 6.

This session took place before the metallographic samples from the preceding sections had been examined and the fact that the extremely rapid annealing applied to sections 3 and 4 had proved inadequate was not then known.

Section 5 was also hammered with the copper hammer, which, although very distorted, was held together by its central iron collar and continued to perform well. Some cracking appeared at the back of the T section but none was present at the edge. This section was also very rapidly annealed at 560^{o}C and air cooled.

During the second hammering it became clear that the distortion of the hammer head was resulting in an automatic 'scooping' action similar to that we had used on section one and that the hammer was adapting itself to the angle of the edge which made hammering somewhat easier. Once this section had also suffered a 70% deformation the edge, before sharpening, was sufficiently thin to make a substantial cut in the edge of a block of three quarter inch thick plywood, as shown in Plate 3.1.3(i).

Section 6 was again hammered with the copper hammer, to approximately 50% deformation, with good results and no anvil damage. A rapid anneal to 570^{o}C was followed by air cooling and a second hammering using a small copper hammer, which, although it took longer, produced a neater edge with deformation of around 70% evenly along the length of the section.

Section 5 was ground manually, using first an aluminium oxide sharpening stone and then given a wet polish with a special very fine stone of Danish origin, which is known to have been imported and used in the Middle Ages (Robert Seaton - pers. comm.). This method proved much less 'wasteful' of the hardened edge and produced a very fine sharp blade. Section 6 was sharpened similarly but instead of producing a single angled edge a second more acute angle was introduced close to the edge giving a wedged effect similar to that used on an axe blade. This latter technique adds considerably to the strength of the edge.

It was decided, in case the treatments used to produce the edges proved disastrously wrong during the experimental edge damage replication, to leave the final section untreated as a back up.

Subsequent metallographic examination of samples from the centres of sections 5 and 6 showed that they, like sections 3 and 4, had not been adequately annealed. All four sections were therefore annealed in the laboratory in a gas furnace. They were brought up to a temperature of 570^{o}C, as measured by a thermocouple, kept at that temperature for one minute, removed and air cooled.

All four then showed a recrystallised structure with very small twinned grains, although none was fully homogenised. Given that this treatment would have removed some, if not all, of the work hardening it was decided to rehammer two sections, 5 and 6, to 'medium' hardness and re-sharpen these by hand, with the resultant microstructures being as shown in Plate 3.1.3(ii)-(iii). The other two sections, 3 and 4 were left without further hammering, with the microstructues as shown in Plate 3.1.3(iv)-(v). Thus there were two very hard, two medium and two annealed sections available for experimental replication of edge damage, reflecting the range of microstructures and hardness observed in the archaeological sword samples.

3.1.4 Blade Edge Finishing - Summary

There were several unforseen problems encountered while producing the finished edges but most of these were due to the shape of the T sections and would therefore not have applied to the production of a finished sword.

It proved possible to hammer the edge and deform it sufficiently to produce a very thin edge without the expected need to perform very frequent annealings. The annealing process itself required great care as high temperatures did seem to induce subsequent cracking, even of metal which had been cooled, while too low a temperature or too short an annealing time failed to recrystallise the metal. On the other hand, even in those cases where subsequent microstructural examination showed that recrystallisation had not taken place, there did seem to be some improvement, albeit sometimes only slight, in the 'workability' exhibited by the metal after heating.

The copper hammers used performed surprisingly well, despite rapid deformation, and produced an edge finish which was superior to that given by steel hammers. O'Faolain (1997) used a large round 'pebble' and a small bronze replica hammer and found the latter infinitely superior.

Although the surface of the iron anvil eventually became a problem and it is likely that a bronze anvil would also have become brittle enough to chip under an inaccurate blow, the results achieved were, on the whole, adequate and any unsightly marking could be removed by subsequent grinding. O'Faolain (1997) used a wooden anvil and also deemed the results satisfactory, although it appears, from his photographs of the swords and the final microstructures, that the edges of his swords, as cast, were rather thinner than those on the sword sections and therefore the metal was not so greatly deformed during working.

A summary of the treatment of the sections and the micro-hardness of samples taken from the sword sections before edge damage replication are set out in Table 3.1.4(i)

3.2 Replication of Edge Damage

A Monsanto Tensometer Balanced Impact Machine, as shown in Plate 3.2(i) was adapted to test the effects of various impacts on the edges of the sharpened blade sections.

One arm of the machine was 'disabled' by being wedged so that it was held away from the vertical. A large wooden block was set in the space left at the bottom of the vertical held in place by two large bolts inserted through the holes for the safety bar which normally locks the arms in the vertical position when not in use. Initially the bolts were inserted through the wooden block but the block split on the first impact and subsequently the new block was set in front of the bolts which prevented it from being pushed back by the impact.

The other arm of the machine was left to function as usual. It is held in its highest position on a notched lever and is released by manual operation of a latch mechanism. This delivers a force of approximately 44 Joules, as measured by swinging the one arm, unimpeded, through the vertical with the tensometer, which normally measures the residual energy after impact, engaged. This striking energy is roughly equivalent to that absorbed in breaking a 1 cm square section bar of high carbon (0.35%) steel with added molybdenum (0.79%) and nickel (1.9%) or of forged aluminium bronze (88%Cu, 9%Al, 3%Fe) (Bailey 1960, 459).

Although it is certainly not the maximum striking energy which could be achieved by two strong and experienced combatants wielding large swords and striking each other simultaneously, it is well within the range which would be expected to occur in combat and may be compared with measured observations in sporting contexts, such as the approximately 95 Joules of a 130mph tennis serve, an impact in which, due to the elasticity of the racket, very little energy is lost (Hawkey 1991, 54).

The sharpened blade sections were cut into 10 segments, of approximately 2 cms width. Each was photographed and then set into pre-chiselled recesses in small cubes of wood. These were of two types; the first arranged so that the blade sat vertically upright from, and parallel with two edges of, the upper surface, as shown in Plate 3.2(ii)-(iii), and the second so that it emerged at 45 degrees to, and in the line of the diagonal of, the upper surface, as shown in Plate 3.2(iv)-(v).

The segments were secured by taping pieces of wood across the arms of the T section which had been sunk into the block. The blades were thus held relatively firmly but could, on a sufficiently hard impact, rotate around the line of the spine. This movement, which causes a sliding contact, is typical of actual blade on blade impact in combat (Robert Seaton - pers. comm.) since the 'give' of the wood mountings mimics the manner in which the grip of the combatant absorbs a heavy blow.

3.2.1 Blade on Blade Impacts

The blade segments, set in the small wooden cubes, were taped to the large wooden block and to the arm of the machine. The arm was then raised to its highest position and released to cause a blade on blade impact. All blades attached to the large wooden block were vertically mounted. Those attached to the machine arm alternated between straight mounting so that the edges met at right angles on impact and angled mounting so that the edges met at angles of 45 degrees in two planes. Each segment was impacted once only. The small wooden cubes were re-used but, being prone to fracture, gave rise to a variety of types of impact. They had to be replaced several times during the course of the experiment. The mode of impact was noted and the segments were photographed after the impact.

3.2.2 Further Impact Modes

In addition to blade on blade impacts, four further series of impacts were tested:

i) Blade segments, mounted on the arm of the machine, were impacted onto a full blade section (85% Cu, 10%Sn, 5%Pb) taped flat against the large block so that the segment edge impacted the slightly rounded face of the blade.

ii) Arm mounted segments were impacted on block-mounted hardened hide to simulate blade on shield impacts (a few impacts were subsequently made on hard wood (mahogany) wrapped in hardened hide).

iii) A few blade segments, mounted on the large wooden block, were impacted by a heavy leaded bronze socketed axe blade, cast in a previous experiment. The axe blade had been ground but had not been worked to harden it and it therefore suffered rather more damage than the sword edges. Given the relative shortage of blade segments and the considerable time required to harden and regrind the axe edge it was decided not to proceed further with axe impacts.

iv) Finally a substantial knuckle joint of lamb was taped to the large wooden block and impacted by blade segments mounted on the machine arm to replicate the effect of a blade hitting flesh and bone.

3.3 Results

In order to summarise the results it was necessary to codify and simplify the range of impact damage and the terms used are defined as follows:

Bowed = distorted about the line of the edge in a fairly sinuous curve whose depth is less than its length.

Chipped = having lost a piece of metal whose depth is less than its length.

Notched = having a v shaped distortion, depressed below the line of the edge or distorted about the line of the edge in a curve whose depth is greater than its length.

Nicked = having lost a piece of metal whose depth is greater than its length.

Scored = having a long, fairly narrow indentation along the surface.

Torn = having a jagged rip in the metal without any loss of metal.

Examples of each of the above are shown in Plate 3.3(i)-(vi). The damage has been photographed on either side of the blade and on the cutting edge itself at a magnification of approximately 5.8X.

The edge to edge impacts gave rise to a wide range of results. In almost all cases there was at least some element of compaction, although further damage disguised this in many instances. Compaction is most immediately obvious in the specimens which were notched and much less clear in those which were bowed, especially those which had chipped.

In six of the eighteen cases a definite double impact, as shown in Plate 3.3(vii) occurred, generally due to a sudden breakage or movement of the mount. Where these double impacts have caused separate areas of damage (denoted by 'twice' or '+' in the results table) each area has been dealt with separately in what follows.

There was a marked difference in the morphology of damage between the perpendicular and angled impacts. While the results of the former were approximately evenly split between bowing and notching the latter split approximately two to one in favour of bowing. This comes about because the initial impact tends to stretch the relatively thin edge of the sword outwards when the blow is angled while the initial effect of a perpendicular blow is to compact the metal directly below the point of impact.

The differences between performance of the three differently finished blade edges, the fully hardened, partially hardened and annealed were much less marked. In particular the partially hardened and annealed blades showed very similar results. This is undoubtedly due to the relatively light final working applied to the former and the residual hardness of the annealed blade edges due to the shortness and low temperature of the annealing process. Although differences in performance between the fully hardened blades and the others were not statistically significant, they did match expectations based on their microstructural characteristics. Thus the fully hardened blades were almost equally likely to bow or to notch while the others were twice as likely to bow rather than notch. Similarly the fully hardened blades showed greater brittleness in that in around 75% of cases the metal either tore or splintered off completely while the others only showed such damage in approximately 50% of instances.

The effects of the edge on blade face impacts, which mimic defensive use of the flat sword in parrying a blow, were very similar across all the edge categories, although the damage to the fully hardened edges was rather less. All of the edges bowed to some extent and all caused a substantial score mark on the surface of the relatively soft leaded sword section, as shown in Plate 3.3(viii).

All of the blade edges, whether the blow was angled or not, cut into at least one layer of the hardened hide with no visible damage to the blade. The relative elasticity of the hide did however mean that it performed rather better defensively than wood. When the final two blade edges, one partially hardened and one annealed, were impacted on a piece of hardwood 'shrink wrapped' in hide, the edges cut into both hide and wood with no visible damage to the blade, although one blade lodged fairly firmly in the wood as shown in Plate 3.3(ix). Previous experimental work (Coles 1962, 185) has shown how easily a sheet metal shield can be cut without any great damage to the blade and the effect of mounting sheet metal on wood, a method which Coles discounts because of the handles attached to the beaten metal shields of the period, is likely to be similar to, but less effective than, covering wood with hide.

The four blade edges subjected to impact with an unhardened axe blade, shown in Plate 3.3(x), were all quite heavily notched and, in all but the case where there was a distinct double impact, the metal was chipped or nicked. The notches on the sword edges were somewhat wider than those caused by impact with another sword edge and were relatively shallow, while those on the axe blade, shown in Plate 3.3(xi), were rather deeper. The relative depths of the notches is most likely a result of the softness of the axe blade used and it would be expected that a hardened axe blade would inflict greater and deeper notching on the sword edges, while suffering much less damage to its own blade.

All of the blades showed virtually no damage, apart from possible slight blunting, when impacted on the lamb joint. However, they all cut through the flesh of the knuckle joint and exposed the bone, with greater tearing of the meat when the blow was angled. In three cases the bone was scored and in the other three the bone was cracked with, in one case, a chip of bone removed completely, as shown in Plate 3.3(xii). There can be little doubt that such blows on unprotected limbs would be, at least temporarily, disabling and that one which impacted the neck would most probably be lethal.

The full sequence and results of impact testing are summarised in Table 3.3. The physical results are illustrated in Plates 3.3 (xiii)- (xliii). In the illustrations the two photographs of the edge prior to impact, showing one side and the cutting edge, are followed by three photographs of the segment after impact, showing either side and the cutting edge. Some areas had been sampled before impact and this is clear from the photographs.

The experimental results lead to the conclusion that damage to the edges of swords requires a substantial impact with material of similar or greater hardness. The organic materials tested, which, although capable of absorbing a blow, were substantially damaged in the process, inflicted no real visible damage on the blade edges. The type of edge damage inflicted by metal on metal impacts varied according to the type and angle of impact as well as the hardness of the metal and the fineness of the edges concerned. There was a clear morphological difference between a heavy impact with a sword edge on another such and a heavy impact between a sword edge and a typically thicker axe edge.

3.4 Impact Damage from Actual Sword Fighting

Two swords, shown in Plate 3.4(i)-(ii), which had been used by Helgi and others in actual fight practice were examined. The swords were made from mild steel and the edges were rounded, not sharpened or hardened. They had been used in sword fighting for approximately two hours and the edge damage exhibited was purely that caused by that one episode since, as mentioned above, all such swords must have their edges smoothed before use.

Although the edges were blunt and relatively soft, the deformations seen, as shown in Plate 3.4(iii)-(xii), are similar to some of those shown by the experimental bronze edge sections. There is a greater prevalence of the longer sections of damage caused by a 'sliding' impact, as shown in Plate 3.4(viii-xii) since the swords were obviously much less restricted in their movement than the small, mounted, bronze edge sections. There are no cases where the blade edge actually splintered since the metal is relatively soft.

These damage patterns, when the differences in edge morphology and hardness are taken into account, do indicate that the experimental edge damage described above was reasonably representative of the types of damage which would result from actual sword fighting and may therefore be used to provide a basis for comparison with ancient edge damage on bronze swords.

4 Physical Characteristics of Weapons

4.1 Methodological Considerations

In order to examine the weapons systematically it was necessary to 'impose' some ordering on both the weapons and the characteristics to be investigated. The ordering is essentially subjective, reflecting those aspects of the weapons' 'biographies' where there appeared to be the greatest probability of ascertaining patterns relevant to the questions of regionality and social context and those characteristics which seemed intuitively to be most strongly related to the aspects concerned.

The examinations were not designed to prove or disprove posited theories but to provide an evidential framework for formulating interpretations. The subdivision of the weapons is based on geographical location of deposition and on typology. The subdivision of the typological characteristics has been made by considering those most strongly correlated with their 'design', 'manufacture' and 'use'. All three of these are modern concepts familiar to all who function within a Western industrial society but require further definition for the purposes of this study:

> A design is a conceptualisation which enables the designer to define an object with detail sufficient to enable its creation in material form.
>
> To manufacture is to make by hand - a reversion to the literal translation which effectively excludes the modern concept of production on an industrial scale.
>
> Use is the performance, with the artefact, of physical, purposeful action.

4.1.1 Typology

The study of Late Bronze Age weapons has a long history and the tradition of 'classification' of the weapons into 'types' based on morphology followed rapidly upon the early descriptive (e.g. Evans 1881) treatises. These traditions are now so ingrained that it is almost impossible to study the objects without adhering to them. It should be remembered that these are generally not true 'classifications' but are simply groupings of objects based on perceived similarities, however 'objectively' defined, and that as perceptions may differ so may the groupings. Thus, to someone to whom the size of a weapon is of overriding importance, a grouping of objects based on the niceties of rivet hole configuration may seem incomprehensible.

It is therefore important to be aware of the choices being made in grouping archaeological artefacts and the implications of the relative importance thereby attached to the various characteristics being considered. The problems are further compounded by the fact that a grouping, even though it is consistent and clearly defined, may well bear absolutely no resemblance to any grouping which would have been recognised as such at the time the artefacts were in circulation. Such comments apply equally well to both intuitive and 'objective' groupings since even the latter are entirely dependent on the algorithms used (Read 1982, 60).

Certain aspects of the criteria used to establish typologies are therefore open to debate as to how much they represent differences which would have been regarded as real by the makers and users of artefacts. A distinction is drawn between these two groups of people in that they themselves may well have had different criteria for assessing differences between artefacts. It is feasible, for instance, that certain aspects which would have been recognised by the first group would either be hard to detect, e.g. flanges, or not visible at all, e.g. the difference between slots and individual holes for rivets, once the weapon was completed.

There has been little typological consideration given explicitly to characteristics directly relevant to the utility of the artefacts and that which has been implicit has often resulted from a concept of ranking by general 'technological development'. A presumption that the makers and users of artefacts were unthinking participants in a form of 'escalator ride' to technological 'superiority' underlies, and to some extent undermines, many archaeological interpretations. The adoption or rejection of any new technique is likely to have been the result of many factors, among which both utilitarian and cultural considerations may have been vital, either in perceiving a need for and sanctioning its use or in rejecting it altogether as either unnecessary or in contravention of prevailing beliefs.

This is not to say that typological analysis of bronze artefacts is pointless or that currently accepted typological systems are 'incorrect'. On the contrary, it would appear from such independent evidence as exists that many are largely both useful and broadly 'correct', in that they do group artefacts in a manner which facilitates further analysis. The typologies of weaponry which exist in the current literature are the result of a long series of studies by numerous scholars and although often used directly to define chronological sequences, based largely on ranking of stylistic 'development', they have also been shown by independent dating methods to have been correlated with changes through time, at least in certain well studied geographical areas.

The weapons have, herein, been subdivided into typological groups in order to assist with interpretation of the data collected where such subdivision is helpful and relevant. Comments on the criteria for such typological subdivision are included under the appropriate heading.

4.1.2 Design

The concept of creating a unique design from scratch to produce an artefact for a particular purpose is probably alien when looking at the social context of the Late Bronze Age. The imposition of an 'evolutionary' model does seem to suit the bulk of the data. Most specialised implements do appear to have been the result of developments of simpler tools. Breaks in such a sequence and abrupt changes are infrequent and those which do occur can frequently be attributed to the adoption of a type which 'evolved' differently elsewhere. It cannot be assumed that all adaptations and adoptions were necessarily optimal from a utilitarian viewpoint, some even appear to have been the opposite, but many probably conferred some practical benefit in addition to satisfying a social, aesthetic or religious requirement.

The nature of artefact production in bronze, however, demands the existence of a physical as well as a mental template. Unlike the relatively gradual and cumulative procedures used when working in wood, stone or clay the process of casting is effectively instantaneous and discontinuous; the mould, once made, largely dictates the final form and the metal is changed from a freely flowing liquid to a solid object in a matter of seconds. The bulk of the formation process is thus completed and further working, in general, only creates relatively minor changes in the morphology. Thus, in essence, the template used to form the mould is the result of a well nigh complete design procedure and the scope for subsequent alteration of the final object, short of its total destruction, is decidedly limited. When looking at a bronze object one is therefore contemplating simultaneously the culmination of a sequence of artefact development and a single design produced by an individual.

4.1.3 Manufacture

The processes involved in manufacturing a bronze weapon, as deduced from the material residues and artefacts which have survived in the archaeological record and from experimental reproduction, are described below. These are the bare bones which are necessary for the existence of the objects in the state in which they are found today. They do not in any way comprise the full panoply of ideas or activities which took place before the object appeared in its completed form but they must have been a part of that reality. The remarkable consistency in the fabric of the weapons has already been noted in Chapter 2 above. How far our modem 'knowledge' of the processes was mirrored by that of the makers is a matter of conjecture - some items from our 'knowledge menu' are obviously not applicable in prehistory, others may have been very similarly appreciated and yet others so differently 'known' as to be unrecognisable.

The majority of weapon moulds which have been found were made from clay. This material seems to have been the optimal choice for sword casting, as shown by the moulds from Dainton (Needham 1991) and Springfield (Needham 1987) and for casting any relatively long spearheads. There is evidence for the casting of long channeled spearheads in clay moulds at Grimes Graves (Needham 1991) and of basal-looped and a probable lunate-opening spearhead from Dainton (Needham 1980).

There is a stone mould piece for casting a side-looped spearhead, which would precede the period under consideration, from Bodwwrdin, Anglesey (Hodges 1960) but little evidence of moulds for other smaller types exists. It is possible that such items were cast in moulds formed entirely from sand mixed with clay within a two part wooden frame, still a relatively common method, which would leave no recognisable trace.

However, there are numerous examples of socketed axe moulds in bronze, stone and clay (Hodges 1959 and 1960) and evidence of the use of sandy clay cores (Tylecote 1987, 225) and of chaplets, small pins to hold the core accurately in place, made of metal (Northover 1982, 94) and organic material (Craddock in Needham 1982, 12-13).

A bronze mould would itself require expert casting and if the charge were to be heated to a high temperature in order to prevent premature freezing when casting long narrow objects, there is considerable danger that the object could fuse with the mould. A sand mould is obviously less stable when handled leaving a possibility that small amounts of sand could be dislodged and could halt the metal flow. It is also extremely difficult to pre-heat a sand mould, rendering this medium less than ideal for long narrow castings which could freeze before complete filling occurs.

Clay mould fragments themselves appear to have resulted from very similar practices both in mould preparation and bronze casting regardless of the area from which they came. The moulds and casting waste reveal how the items were cast, as can be seen in the detailed reconstruction of the processes within the Dainton report (Needham 1980, 181-4) and in the Petters report (Needham 1990, 71). Two clay mould pieces, one for a Ewart Park sword from Springfield Lyons in Essex and the other for a fillet defined spearhead from Sandy Lane in Gloucestershire, are shown in Plate 4.1.3(i)-(ii).

The pattern, most probably wooden, was pressed into a strip of well levigated clay, thoroughly mixed with fine sand, to provide refractory properties. O'Faolain (1997) suggests the use of a hollowed wooden former to contain the damp mould material and provide ease of handling prior to thorough drying and baking of the mould. The Dainton moulds showed no signs of having enclosed wooden splints although others from a number of sites, such as Jarlshof and Traprain Law, were reported to have done so (Needham 1980, 184). Needham (1980, 183) suggests that the first contact face was then trimmed with the pattern in place and this valve was dried before the second valve was formed.

O'Faolain (1997) mentions problems caused in experimental work by clay cracking during drying if dried too fast or if wooden splints are inserted and also mentions (1997, 164) the considerable shrinkage, approximately 10%, between pattern and final product, most of which seems to result from clay, rather than metal, shrinkage. The shrinkage of a 10% tin bronze cast in sand would amount only to 1.6%, if properly fed (Campbell 1991, 175-240) and, although venting and ingate arrangements for a prehistoric clay mould could cause some variation, the shrinkage should be around this level (Northover - pers. comm.). Crucial here, it would appear, is the extent to which the clay is dried before valve formation. Needham's suggestion of forming the second valve after drying the first can only work if there is very little scope left for shrinkage in the clay used to make the second valve.

If both are still wet, the contact faces of the two valves must be separated by a fine layer of powdered material to prevent sticking. Once the second valve is formed the two valves may be separated and dried, after removal of the pattern and formation of the pouring gate. The outer wrap has been found generally to be made of less well prepared clay than the inner valve and is usually applied as a continuous wrap around the junction

(Needham 1980, 181), although it may have been discontinuous elsewhere. Again differential shrinkage could cause problems if a wet outer wrap is applied to dry valves and it may be that this was alleviated by the outer wrap having a coarser structure and increased porosity, caused by burning out of organic material, as has been seen in microscopic analysis (Howard 1980, 192). There is evidence of inner valves having been bound together before application of the outer wrap (Needham 1980, 182).

O'Faolain's best results were achieved when casting into moulds which had been baked but not cooled, at a temperature of 500-600^{o}C, although surface quality was rather variable (O'Faolain 1997, 168-9). The preheating of the mould did seem to assist in preventing incomplete castings due to premature freezing of the bronze in the mould. The metal would have been poured with the mould at a fairly shallow angle (less than 45 degrees to the horizontal), as evidenced by casting jets (Northover 1988, 131), to reduce turbulence and permit gas expulsion.

A number of factors could produce failures in casting; cracking of the mould, movement of a core, inadequate pouring temperature, failure completely to fill the mould, shrinkage cavities, turbulent metal flow and excessive gas ejection, causing porosity or even explosion, are among the most common. Success in casting, even by skilled craftsmen, was an uncertain prospect and it is hardly surprising that what little evidence there is supports the use of wooden patterns rather than of a well cast bronze weapon, which would have to be left unfinished in order to use it as a pattern

Metallographic analysis, as described in Chapter 2, is required to reconstruct the sequence of post casting production. Many Bronze Age metal artefacts could simply have been cast, fettled and ground to a smooth finish but weapons and tools with cutting edges were usually heavily worked. The inclusion distortion in the samples examined, as shown in Chapter 2.3.3 above, indicated that a minimum of 55% of the samples came from areas of the weapon which had been heavily worked, and the figure rose to a minimum of 61% where attention was restricted to swords. The distribution of grain sizes for weapons which were not burnt, as shown in Chapter 2.3.7, also indicated that a high proportion of the weapons had very heavily worked edges. Grain size is partly dependent on the deformation undergone, with small grains indicating substantial deformation and the three groups with the smallest grain sizes constituted 61% of weapons and 68% of sword samples while the two groups with extremely small grain sizes (less than 15 micrometres in diameter) constituted 47% of the weapon samples and 50% of sword samples.

As shown in Chapter 2.3.5 above, the extent of coring within the microstructures of the samples, the vast majority of which were taken from the outside edges, i.e. the areas most likely to have been annealed, shows that annealing temperatures were low and that annealing periods were of short duration. Only 26% of those weapons, which showed at least some recrystallisation, showed no coring at all and this fell to 12% when samples with typical burnt microstrures were excluded. The large cross sections of swords examined, described in Chapter 2.5 above, all showed that recrystallisation was largely confined to the cutting edges of blades and the outer surface, again indicating that temperatures were only just high enough to recrystallise the bronze and that the weapon was not heated for long enough to attain that temperature throughout. Less than 10% of weapon samples showed no recrystallisation whatever showing that they had not been annealed, or at least that the area sampled had not reached the required temperature for recrystallisation. As was discovered during the experimental work described in Chapter 3, it was all too easy, when using a small brazier, to recrystallise stretches of blade edge while leaving others unrecrystallised.

The combination of extreme deformation of the outer edge and the very limited annealing, as indicated by the inclusion distortion, the small grain sizes observed in most weapon edge samples, the coring of the majority of samples and the incomplete recrystallisation of some, shows considerable skill on the part of the edge finishers. This was especially true of the swords although a number of the spearhead samples showed similar prowess. In order to achieve the thin even edges seen on most of the weapons examined it was probably necessary to hammer and anneal several times before the final hammering and grinding took place but the experimental work showed that it was possible to produce the deformation seen on the museum weapon edges with only two hammerings, even when the intermediate 'anneal' had not reached a high enough temperature to recrystallise the metal.

The failure rate in casting and finishing the more difficult objects, in particular long thin weapons such as swords and large spearheads, was probably high. There is evidence at Rathgall of a partial bronze blade fused within the clay walls of a mould (Raftery 1971). Even if cast seemingly successfully cracks can and do appear, due mainly, it seems, to firecracking on heat treatment and porosity within the initial cast. These are examples of errors in failed castings, such as those reported from the Isleham hoard (Northover 1982) and in a number of weapons with very poor surfaces and visible porosity. The ease with which breaks and cracks may occur during post casting treatment, from flash removal, rivet hole perforation, incorrect annealing temperature and edge hammering has been shown in recent experimental work (O'Faolain 1997). The most common faults seen in the surviving prehistoric weapons are porosity and casting faults, together with repaired hilts where the top was cast on to remedy either an incomplete casting or a broken tang. an example of surface porosity and a cast on hilt are shown in Plate 4.1.3 (iv)-(v).

During the efforts to replicate the microstructure of the sword edges for experimental purposes, described in Chapter 3, it was forcibly brought home just how difficult, painful, tiring and time consuming this work was. During other experimental procedures similar experiences have been reported (e.g. O'Faolain 1997). The finishing shown in the vast majority of the weapons examined has not been achieved in modern experiments without resort to modern, preferably powered, tools. If no such shortcut is available or acceptable, the object has generally been left in a state in which no Bronze Age artisan would have let his work be seen.

4.1.4 Use

We are here concerned with physical use of the weapons and the direct material effects thereof. The symbolic and ritual aspects of weapons and activities in which they were involved is considered in detail in Chapter 5 below although it is readily acknowledged that such a separation is merely an artificial construct. The rationale behind making the distinction lies in the desire to establish whether there exist patterns of direct physical use which vary according to regional, chronological or typological groupings and to attempt to deduce the possible forms of combat in which the weapons were used. This approach follows that taken when analysing the manufacture of the weapons in that the information deduced forms but a part of a much more complex whole but the part in question is that which is most accessible to us.

4.2 Swords

Some 499 swords and pieces of swords were examined and analysed. However these included some with no provenance, some whose typology was indeterminate and substantial numbers where one or more characteristics could not be assessed. The totals which were included in each of the tests are set out in the relevant tables. It must be remembered that we are here dealing only with swords which were deposited and retrieved in modern times. Swords which were recycled in prehistoric times or which corroded away leaving no trace and those which were deposited and recovered in the distant past, or have thus far evaded discovery are obviously not included.

4.2.1 Sword Typology

The four groups of swords, Early, Wilburton, Ewart Park and Late, used for the purposes of this study, were described in Chapter 1.2.1 above and examples are illustrated in Plate 4.2.1, at approximately one sixth of their actual size. The groups are widely accepted as being in approximate chronological succession with the first and last groups consisting of several types which were combined herein due to their relative chronological positions, while the each of the two central groups consists of one widely accepted type.

For the purpose of this study, as mentioned in Chapter 1.2.1 above, the shoulder width and shape has, in part at least, been taken as more vital than certain other features and, as a result three swords with some Wilburton characteristics and deemed to be 'Wilburton - Variant G' by Colquhoun and Burgess (1988, 51) were re-classified as Ewart Park. This was done mainly because it seemed better to fit the regional variation in distribution and did not disturb the broadly accepted chronological succession. A different grouping based on blade style would, for example, effectively have split Colquhoun and Burgess' Wilburton variants into the generally larger, lozenge cross-sectioned blades, comparable with many of the early swords and the normally smaller blades with lenticular cross-sections, which are more like the 'standard' Ewart Park blade. Such a grouping would again broadly preserve the chronological framework, except for some minor differences within the swords with Wilburton characteristics.

Certain physical parameters of the swords were measured and compared across the typological groupings, which have traditionally been defined by morphology and not dimensions. The discrepancies caused by the rapier like partial hilts of the Ballintober type swords (the first of the Early group in Plate 4.2.1) mean that the hilt lengths of these have not been included in the statistics for Early swords. Those swords in all groups with integral pommels (such as the first of the Ewart Park group in Plate 4.2.1) or extensions for pommel attachment (such as the last of the Late group in Plate 4.2.1) were also excluded unless it was obvious where the hilt would have ended had there been a 'normal' terminal. This particularly affected the Late group of swords. The results of the comparisons are set out in Table 4.2.1(i) and the distributions for the characteristics are illustrated in Figures 4.2.1(i)-(ix).

All of the means were tested pairwise for equality using Student's t-distribution (Shennan 1988, 306). This test requires that the data for each of the groups to be compared form a normal distribution and measures of skewness and kurtosis for each of the groups were examined in order to ensure that they fell within a range compatible with the assumption of normality. All differences described as significant in what follows were shown by the test to be statistically significant at the 5% significance level

The heterogeneity of the Early group is clear from the ranges and standard deviations observed in the data. The statistics for the Wilburton type, although the blade means lie between the Early and Ewart Park types, have more in common with the Early swords. Indeed there were no statistically significant difference in means between the Early and Wilburton groups whereas the blade width and the ratio of its thickness to its width were the only two statistics for which the means of the Ewart Park and Wilburton groups were not significantly different. The averages of the measurements show clearly the relative narrowness of shoulder and shortness of blade of the Ewart Park type.

The reversion to wider shoulders on the Late group meant that there was no significant difference in mean shoulder width between it and the Early group. Late swords are both longer and narrower in blade than any others, although the mean blade thickness is not significantly different from that of the Early or Wilburton groups. The increase in length is a reversal of the tendency to reduced length seen from the Early to the Ewart Park swords and, although the decreased blade width is a continuation of previous change, the shape is very different and the decrease is so large that this too smacks of discontinuity. The ratio of hilt to blade length in the Late group, however, differs significantly only from that of the relatively short bladed Ewart Park group.

Certain ratios underline the morphological differences and, while no combination would completely discriminate between types, the low ratios of shoulder width to maximum blade width and to hilt length, together with the high ratio of hilt length to blade length, do single out the Ewart Park type. Similarly it is the narrowness of the relatively thin blade which makes the Late swords stand out in the ratios of blade thickness to width and, especially, of shoulder width to blade width.

To some extent it could be said that the statistics merely recognize the manner in which the groups were defined. This is certainly true of the shoulder width which is the best measure of the configuration given most weight when grouping the swords. However the differences in blade size were given much less weight in the grouping and yet show clearly in the numerical analyses. This may mean that the relevance of the groupings within the time frame of the Late Bronze Age could be better than the defining characteristics would have led one to believe.

Given the clear morphological differences the only comparisons between regions were made within the large group of Ewart Park swords. The results are summarised in Table 4.2.1(ii) and the distributions illustrated in Figures 4.2.1(x)-(xviii).

These reveal significant differences mainly between East Anglia and other regions. The mean shoulder width was significantly greater than in the South East and the mean ratio of shoulder width to hilt length was significantly greater than in Scotland. East Anglian mean blade thickness was significantly lower than in all other regions. These results partly reflect the large number of swords from the Waterden hoard included in the East Anglian data, particularly where they involve shoulder width which is, on average, relatively large for this hoard.

The presence of several of the large 'Caledonian' variant of Ewart Park type (Colquhoun & Burgess 1988, 55) within the Scottish data did lead to a higher mean blade and hilt length for the Scottish Ewart Park swords but this was not statistically significant. Mean blade thickness in Scotland was significantly lower than in the South East as well as East Anglia and the ratio of blade thickness to blade width was significantly lower than in the West. The range of values seen in the Scottish and Northern swords is generally much wider than in other areas, although it is rivalled by the East Anglian in terms of shoulder width and by the South Eastern in terms of blade width.

4.2.2 Sword Design Characteristics

The pattern maker must have been clear as to the style desired, whether it was required by tradition or by the preference of the sword maker or its ultimate owner. It should be noted that, despite the existence of clear similarities in style among the swords, no two among those examined are identical and while some of this heterogeneity may be due to the choices made during manufacture, some at least is due to the original design.

Many of the features 'designed' into the weapons coincide with those used to define the typology. The hilt and ricasso morphology certainly affect the way a sword is held. In particular the ricasso becomes vital if the hilt length is especially short since the option of wielding the sword without use of the ricasso becomes less viable. Widely splayed shoulders may also demonstrate a preference for a grip which does not encroach on the blade area and which is in part 'protected' by the shoulders. However the differences in hilt configuration among the swords studied were not sufficiently large to denote any dramatic change in grip style during the Late Bronze Age. Ricasso styles range from very definite, highly curved to almost vestigial and straight; a ricasso which was largely formed in the mould and exaggerated by edge finishing and another formed by milling the edge after casting are shown in Plate 4.2.2(i)-(ii). The ricasso was still clearly capable of performing its function in the vast majority of swords examined. Many of the differences in hilt and ricasso may therefore be seen as symbolic or stylistic.

Actual applied decoration is very rare, especially among the dominant Ewart Park group, and if present at all it is minimal and confined to the hilt and ricasso area, as is the example shown in Plate 4.2.2(iii). Raised ridges or grooves (and lines) outlining blades, as shown in Plate 4.2.2(iv), could also be construed as decorative, although the former, which is a feature of Gundlingen type swords, may have given strength to a thin edge (Cowen 1967, 416). It is possible that certain East Anglian blades with three 'facets' on either face, like that shown in Plate 4.2.2(v), were intended to be decorative, although they are relatively plain. The main area in which decoration and symbolism could have been expressed lay in the organic hilt plates and scabbard casing which have not survived. A sword could easily have been individually identifiable by means of these elements alone. The surviving decorative bronze elements of later iron swords show just how ornate and individual such items can be (Piggott 1950).

The major factors affecting performance of the sword would be the weight and balance which are mainly determined by the blade shape and length. This is an area where the designer of the pattern must have taken more than appearance into account since the gradation in thickness and the positioning of the widest part of a leaf shaped blade generally has much more effect on the balance than any form of pommel arrangement. The balance of a blade was thus decided when the pattern was produced and was very little affected by any further working.

A measure of the balance of a blade is supplied by calculating the 'turning moment about the hilt' (Bridgford 1997, 104). This is defined as the weight times the distance between the centre of gravity and the shoulders. The effect of using a leaf shaped blade is to increase the turning moment when compared with a relatively parallel sided blade of similar length and weight and its adoption must indicate the intention to use the sword as a slashing weapon. There are advantages in keeping the turning moment relatively low in that using such a blade puts less strain on the wrist and arm but a long heavy blade, with a high turning moment, would obviously provide both a longer 'reach' and a more damaging impact. The latter applies only if the blade is used in slashing mode since, when used as a thrusting weapon in the same manner as a rapier, the extra turning moment provides no real advantage, although Oakeshott (1960, 35-36) claims that it 'helps you to aim it, and in striking adds velocity to its own weight'.

The preference for shorter and less 'heavy' blades on mainland Britain was less extreme than in Ireland, where the mean turning moment calculated for 35 complete Class 4 (Eogan 1965, 10-13) swords was 9125 cm.gms (Bridgford 1997), but is clearly manifest in the comparable Ewart Park group, with mean 11692 cm.gms.

The typological groups each provided a sufficient number of complete swords to calculate the mean turning moment for the group. All of the means were tested pairwise for equality using Student's t-distribution (Shennan 1988, 306). This test requires that the data for each of the groups to be compared form a normal distribution and measures of skewness and kurtosis for each of the groups were examined in order to ensure that they fell within a range compatible with the assumption of normality. All differences described as significant in what follows were shown by the test to be statistically significant at the 5% significance level

The tests showed only that the mean turning moment of the Ewart Park group was significantly lower than that of the Early and Late groups. Subdivision of the Ewart Park group into geographically defined groups did not show any significant differences in mean turning moment although the range of the Scottish and Northern group was noticeably the widest. The East Anglian mean turning moment was lowered by the inclusion of the miniature sword found at Flag Fen whose dimensions fell substantially outside the normal distribution. The results of these analyses of this functional design characteristic are summarised in Table 4.2.2(i) and the distribution is illustrated in Figures 4.2.2 (i)-(ii).

4.2.3 Sword Manufacturing Characteristics

The manufacturing process starts with the production of the mould from the pattern which incorporates the overall design concept. If clay is used as the mould material, shrinkage on drying would have to be allowed for when producing the pattern. Probable mould production and casting and finishing procedures are described in Chapter 4.1.3 above.

The moulds, where it can be ascertained, were bivalve and would therefore leave a casting 'flash' of excess metal around the edge, where the two valves meet. This has to be removed when the sword is broken out and, if there is a lot of flash, this can be quite a brutal process bringing with it a high risk of damage or breakage. It is therefore unwise to attempt to form a very thin edge in the mould. This would generally preclude the use of finished swords, with fine edges, as patterns. None of the mould pieces examined to date even includes an edge bevel although elements, such as the semi-circular sectioned beading strip on the inner edge of the bevel of many 'Gundlingen' type swords, must have been incorporated into the pattern.

Drawing a typological distinction between slots and holes in sword hilts may occasionally be misleading. Any attempt to form rivet holes, even partially, during casting runs the risk that the metal fails to flow completely around the uppermost impediment, creating a continuous slot between that and a lower one, as evidently happened in the two cases shown in Plate 4.2.3(i)-(ii). This depends very much on the pouring temperature and the narrowness of the void in the mould at the point of constriction. A slot in the hilt may not, therefore, have been an intentional feature but the result of attempting to avoid having to drill or punch rivet holes combined with a slightly low pouring temperature during casting. As such it may not be the major chronological marker it is often taken to be. However, slots do weaken the hilt and it would have been best to avoid them in weapons destined for physical use.

The presence of a large number of rivet holes is puzzling from a practical viewpoint; if formed or partly formed during casting they cause flow problems and, if they are not pre-formed, there is considerable danger that the hilt will break at some stage of their subsequent formation as has happened during experimental bronze sword making (O'Faolain 1997, 193). Moreover they weaken the entire hilt structure so that it is more likely to break during use. They may of course have been purely decorative, performed as a 'badge' of ownership or rank, or the numbers may have had some mystical significance. More prosaically they may have demonstrated a lack of confidence in the efficacy of the rivets or the strength of the hilt plate material.

Whatever the reason for the excessive presence of rivet holes in early hilts, the numbers in later swords fell to more practically justifiable levels. The unpierced rivet 'depressions' in so many later sword hilts, result from using only minor depressions in the pattern hilt to help locate and form rivet holes, together with a desire to minimise the number of actual perforations made, compatible with securing the hilt plates adequately. The numbers of rivet holes did not rise again until the arrival of very narrow 'pin' rivets, which considerably reduced the tendency to weaken the structure, and even these were generally used sparingly. A 'normal' sized rivet and a 'pin' rivet are shown in Plate 4.2.3(iii)-(iv).

The form of the ricasso, while basically a part of the pattern, may be exaggerated during manufacture by the formation of the blade, either producing or exaggerating existing ricasso notches where the hammered and sharpened edge stops, and this was the case for most of the swords examined.

The edge of the sword, after fettling to remove flash, would have been relatively thick and blunt. The cutting edge would have been produced by hammering the length of each edge, effectively 'stretching' and thinning the metal, and annealing as necessary. Any resultant bowing of the blade would be eliminated by hammering the opposite edge to the same degree. The majority of edges were effectively flat ground but a substantial minority were hollow ground, presumably using rounded grinding stones, as shown in Plate 4.2.3(v). The relative fineness of sword edges is a factor which is significant from a utilitarian viewpoint. There is no ideal level of fineness as the ability to cut, with a razor like edge, must be balanced against the relative weakness of such a thin edge which is more easily distorted or torn.

During examination the swords were assessed visually on a scale of 1 to 5 according to the quality of the casting. This was largely based on the presence of visible porosity on the surface or at breaks in the weapon but also took into account poor surface quality which had not been obliterated by the finishing processes. Such assessments were necessarily subjective and, for the purpose of analysis the five categories were reduced to 3, which could reasonably be described as 'good', 'fair' and 'poor', although considerably less than 5% of those assessed could have been described as 'unacceptably poor'. Approximately 10% of swords, some 53 in number, could not be classified because corrosion or burning had obscured the evidence.

A similar assessment was made of fineness of the edge, where still present or where relatively uncorroded areas remained. The ratings were in five categories, ranging from very sharp to totally blunt. Only 1.4% were effectively blunt, i.e. in category 4, and none appeared to have been unworked. The 3 blunt swords in question were placed in the third category and the number of categories was thus also reduced to three. In this case approximately 20% of swords, some 112 in number, could not be classified because the relative fineness of the edge had been obscured by the effects of corrosion or burning.

The data for casting quality and edge fineness are summarised in Tables 4.2.3(i) and 4.2.3(ii) and illustrated in Figures 4.2.3(i)-(iv). The resulting categorisations of the swords were tested for significant differences using the Chi-squared distribution with 5% significance level. The details of all tests which showed significant differences are summarised in Appendix 1. All differences described as significant in what follows were shown to be statistically significant at the 5% significance level

Only 6% of the swords assessed for casting quality fell into the 'poor' category, with the remainder being split 43% as 'good' and 51% as 'fair'. There was no significant difference in casting quality between the various groups for the swords which could be identified typologically. This being the case swords of all typological groups were divided according to geographic origin. Again, although differences were more marked, with the West and East Anglia having less than their fair share of 'good' quality, they were not statistically significant.

The edge fineness ratings were also tested for differences between the typological groups and although the Wilburton swords appeared to have more 'sharp' edges and the Late group more 'blunt' edges this was not statistically significant and may well have been due to the prevalence of the narrower, less thin, cutting edge which is a feature of the 'Gundlingen' type. However, when the swords were divided according to geographic origin the proportions having 'blunt' edges were significantly higher than expected in Scotland while East Anglia had significantly more, and the South East significantly fewer, 'sharp' edges.

4.2.4 Sword Use Characteristics

The major signs of practical use which are still visible on swords of all types are edge damage and breakages. Approximately 10% of the broken swords were severely bent prior to breakage, indicating a deliberate breaking up of the weapon and not accidental damage in the course of use. Moreover a sword will break at a point of weakness, across a rivet hole or a porosity void in the metal say, whether it is broken in use or deliberately destroyed. This makes it impossible to determine what caused the break in sword pieces which are not themselves severely deformed. Thus this study has concentrated on the edge damage which is more amenable to classification in the light of the experimental evidence.

Close-up photographs of the experimental edge damage were compared with close-up photographs of portions of the edges of swords examined at the museums. There were examples of all the types of damage seen in the experimental edges among the museum swords. A selection of the types of edge damage on museum swords deemed due to combat is illustrated in Plate 4.2.4(i)-(xv) and these may be compared with the experimental results shown in Plates 3.3(i)-(xxx).

The majority of the museum swords examined showed some damage which was morphologically similar to that visible on the experimental blade edges. Moreover the scale of this damage was also very similar. The majority of the experimental damage fell within 2mm of the blade edge and, in general, the edges were affected for less than 5mm of their length. Indeed it was surprising how robust these relatively thin blade edges proved against what were very heavy impacts and how difficult it was to inflict visible damage with anything other than extreme force using metal of similar or greater hardness. In cases where damage of this type and scale is visible on archaeological specimens it therefore seems reasonable to attribute it to use in combat.

When considering the 'repair' of damaged edges by regrinding it must be borne in mind that this may be necessary since a burred blade tends to catch when inserted into or extracted from a scabbard. However, a burred edge can rip tissue and has led to at least one death, due to a severed artery, during re-enactments with 'blunt' weapons (Robert Seaton - pers. comm.). Given the latter point it could well be that small amounts of edge damage, which did not interfere with scabbard use or regular sharpening, were tolerated rather than ground away completely or beaten out. However, it remains likely that the damage visible on many swords is merely that which resulted from their final use in combat.

There were numerous instances of edge damage much more severe than the experimental damage. Often this was due to corrosion but a limited number appeared to have been hacked using a substantial implement, probably a heavy axe, or to have been swung violently against bare rock. Some had suffered damage which was clearly post depositional, in most cases due to ploughing or mechanical excavation. In some cases the timing of such damage was less obvious, thus some of the damage rated as severe may be due to post depositional factors.

The edges of the swords examined were classified according to the damage visible as follows:

1: No damage
2: Some damage but no clear deformation of the metal
3: Damage matching that on the experimental edges
4: Heavy damage, possibly similar in form to that on the experimental edges
5: Very heavy damage with edges clearly hacked.

Examples of each category are shown in Plate 4.2.4(xvi)-(xxi). Where damage was clearly not prehistoric it was ignored for the purposes of classification. Where the blades were corroded or burnt but classification was possible for certain areas the classifications were coded within the database.

Categories 2 and 4 are problematic in that the causes of the damage seen are not clear. The damage in category 2 may be due to corrosion, as in Plate 4.2.4(xvii), or to combat damage which may have been partially ground out, as in Plate 4.2.4(xviii). Approximately 60% of the swords in this category were classified as corroded. Allowing for the fact that some of the corroded swords may have sustained some edge damage which was hidden by corrosion it would appear reasonable to attribute the damage to half the swords in this category to use and half to corrosion. Category 4 damage, if similar in form to category 3, is so heavy as to be unlikely to have resulted from combat. In many cases category 4 damage, like that shown in Plate 4.2.4(xx) is morphologically different from the result of impact of sword edge on sword edge and is more likely to have been the result of impact with a suitably heavy axe or a stone. All damage in this category is therefore best treated as deliberate destruction rather than damage in use. It is of course impossible to determine the state of the edges prior to any deliberate hacking for those swords in categories 4 and 5 but it is highly probable that these swords had also suffered some use damage.

The data are summarised in Table 4.2.4(i) and illustrated in Figures 4.2.4(i)-(ii). The resulting categorisations of the swords were tested for significant differences using the Chi-squared distribution with 5% significance level. All differences described as significant in what follows were shown to be statistically significant at the 5% significance level and the relevant Chi-squared statistics are shown in Appendix 1.

The distribution of the types of damage within the typological groups differs significantly both when considering the four categories formed by amalgamating categories 4 and 5 and when considering the three categories then formed by splitting category 2 evenly between categories 1 and 3 and it was decided to use the latter subdivision throughout. The Early swords had a significantly higher proportion of undamaged edges and a significantly lower proportion of severely damaged edges than the other groups. The two clearly indigenous groups, Wilburton and Ewart Park, when combined, had significantly fewer undamaged and significantly more severely damaged blades than expected.

When testing the distribution of edge damage by typological group within regions it was necessary to restrict consideration to three categories, as outlined above. The only region in which the numbers in each typological group were sufficiently large to permit complete testing was the South East. The proportion of heavily damaged edges in the South East was again significantly low for the Early swords. The proportion of heavily damaged edges was significantly high and the proportion showing 'use' damage was significantly low for the Late group. The South Eastern Wilburton group had fewer undamaged and more 'use' damaged edges than expected. A comparison of the Wilburton and Ewart Park swords from East Anglia showed no significant differences in the distribution of edge damage.

The results of testing the distribution of edge damage, after grouping the swords by geographical location, showed some highly significant differences. The small Western group had no severely damaged edges. In the South East the proportion of undamaged edges was significantly high and the number of severely damaged edges was significantly lower than expected. The Scottish swords were significantly weighted towards the 'use' damage category and the East Anglian towards the severely damaged category.

Analysis of the Ewart Park group divided by geographical location showed the same pattern as that shown by all sword types. The South Eastern group again had significantly more undamaged and significantly fewer severely damaged edges than expected. The Scottish swords had a significantly higher level of 'use' damaged blades and the East Anglian swords showed highly significant levels of severe damage. Comparison of the East Anglian and South Eastern Wilburton swords showed that the

South Eastern swords had significantly more 'use' damaged and fewer severely damaged edges than expected, with the reverse being true of the East Anglian.

The results indicate that regionality was a more important factor in determining the way a deposited sword was used practically than typological factors but that treatment prior to deposition did vary with typology, as can be seen in Figure 4.2.4(i). The tendency for the Early group to show a high proportion of undamaged edges and a very low proportion of severely damaged edges is notable and probably reflects a genuine difference in the final chapter of the 'biographies' of the deposited swords, which do seem to have been deposited undamaged rather than deliberately, and probably ritually, destroyed. However, there was no significant variation among the typological groups in the proportions showing signs of 'use' damage, apart from the Late swords, which did have a relatively low rate of 'use' wear, combined with a high rate of severe damage. The significance of these differences may be both chronological and typological. There may have been a change in the accepted ritual of deposition over time and a different treatment of 'exotic' looking weapons, such as the relatively rare (and 'foreign' influenced) early types and the later, very 'foreign', Carp's Tongue and Gundlingen influenced varieties, from that accorded to the indigenous varieties.

The regional differences, both in treatment immediately prior to deposition and in the extent to which the edges showed signs of use damage, were very definite as can be seen in Figure 4.2.4(ii). While the people of the West and the South East seemed inclined to deposit swords with undamaged edges, the opposite was true of Scotland and East Anglia. However, while those in East Anglia had a tradition of causing severe edge damage prior to deposition, the more common practice in Scotland appears to have been to deposit swords which had probably simply been used in combat.

4.2.5 Swords - Summary

Sword Typology

The results of the numerical analysis of morphological features would tend to increase confidence in the relevance of the typological groupings chosen. It underlines the closeness of the Wilburton group to the Early group and the non-sequential nature of the Late group. Within the dominant Ewart Park grouping the most noteworthy factors are the very wide range of dimensions within the Scottish and Northern group and the significant differences in morphology of the East Anglian swords, with their thin blades and, for the Waterden hoard, wide shoulders.

Sword Design

The extreme rarity of applied decoration on British Late Bronze Age swords is remarkable and indicates that, if used at all, decorative devices are most likely to have been used on the organic material from which hilt plates and scabbards were made. The few exceptions have very limited decoration and often have clear continental affinities.

In terms of design for utility, all but the very earliest swords have hilts which are designed to provide strength when used in slashing mode. The leaf shaped blade design is also clearly intended for this purpose. The range of turning moments calculated was quite wide but the difference between the 'native' types and the more continentally influenced Late and Early swords clearly indicated the local preference for a shorter lighter sword.

Sword Manufacture

As was evident from the metallographic examinations described in Chapter 2 above, the quality of sword manufacture was extremely good and astoundingly consistent given that the conditions of manufacture are likely to have been highly variable. Although microstructural examination is optimal to assess quality the information from visual inspection alone assessed here underlines the consistently high quality of the swords. Even the slight tendency for quality to improve over time is not statistically significant.

The regional variations shown in the edge fineness may be somewhat exaggerated by regional differences in conditions of deposition, resulting in differential preservation of fine edges, but are still likely to indicate that the choices made on the balance between sharpness and toughness varied regionally.

Sword Use

It is clear that few of the swords deposited were unused; less than one in six had edges which could be described as undamaged and a number, even of these, may well have been reground to remove minor damage. Approximately one in four of the blades analysed showed damage sufficiently severe as to support their having been deliberately hacked and/or burned, which does not, of course, preclude their having been used practically beforehand.

It appears that there was some chronological progression in the manner in which weapons deposited were used and abused in that Early swords were less likely to be hacked before deposition than those which followed. However the practice of depositing swords with pristine edges was relatively less common in the two clearly indigenous sword types, the Wilburton and Ewart Park groups.

Regional considerations proved once more to be very important with the South East in particular showing a preference for depositing pristine blades, while in East Anglia blades were deliberately destroyed and in Scotland they tended to have been used before deposition.

4.3 Spearheads

Some 690 spearheads, covering a wide variety of types, were examined. As explained in Chapter 1.2.2 above only tanged and socket looped spearheads were excluded from the subsequent analyses on the grounds that the vast majority of such types pre-date the period under consideration and that the total absence of the latter from weapons hoards in Britain may indicate that any late examples had a different function (Coombs 1975).

The comparatively rare 'protected opening' and more common 'basal-looped' spearheads, which were at their zenith during Needham's Period 5 (1500-1150 cal BC), were included both on the grounds of contemporaneity with Early swords and a few possible later associations (Ehrenberg 1977, 11).

It is possible that some spearheads which are less easy to distinguish as being from earlier periods on morphological grounds may be included in the 556 spearheads left after exclusion of the early types, although the numbers concerned should be sufficiently small as to be immaterial to the results. In the analyses which follow 53 spearheads with indistinguishable blade shape were also excluded, as were 18 with no provenance, leaving 485 to be considered.

In addition to the problems caused by the fact that, as is the case with swords, only deposited spearheads which have survived, been retrieved and preserved are available for study, spears were also likely to have been used for hunting and recent efforts to distinguish between weapons and hunting implements by establishing separate ranges of characteristics for each purpose have not been generally successful (Richard Osgood - pers. comm.). Since all the types of spearhead included have been associated with weapon hoards it is proposed herein to work on the assumption that any used as hunting implements were at least capable of a dual purpose as a weapon. This issue will be further discussed in Chapter 4.3.4 below.

4.3.1 Spearhead Typology

It is proposed herein to follow precedent and adopt a descriptive approach to spearhead typology, as was explained in Chapter 1.2.2, and definitions of the characteristics used in these descriptive groupings are given in Chapter 4.3.1.1 below. It should be emphasised that only those spearheads, all of which have hollow sockets for insertion of the shaft, which are likely to have been in use during the currency of bronze swords are included.

The relative chronological positions of spearheads with certain characteristics were discussed in Chapter 1.2.2. The position of those spearheads with basal loops at the start of the series was clear. Those with characteristics strongly associated with Wilburton swords, in the South East and East Anglia, tended to be somewhat later, while spearheads with ogival blades were generally even later. However, plain socketed spearheads appear to have been present throughout.

In the analyses which follow each characteristic was investigated across all spearheads which possessed it.

4.3.1.1 Definitions of Characteristics

The primary characteristic used to classify the spearheads was, in most cases, the blade shape. The variations considered, as shown in Plate 4.3.1(i) are described below:

***Lanceolate** blades (l)* have sides which form a continuous convex curve from the base to the point.

***Flame-shaped** blades (fl)* have sides which start as a continuous convex curve but change, at the point where the blade reaches maximum width, into a straight line, or become slightly concave, culminating in a long, narrow tip.

***Ogival** blades (o)* ('Watford' type spearheads) are similar to the flame-shaped blades, except that the blade narrows abruptly before the tip and the sides are generally more sinuous. Almost half of the ogival blades had less pronounced outline features and seemed more like lanceolate blades but had the typical abrupt tip.

***Barbed** blades (brb)* have largely straight parallel sides, abrupt 'shovel' tip and a barbed or horizontal base.

***Triangular** blades (t)* have straight sides, although the two base corners may be rounded. Also included under this blade outline were the two 'tear' shaped blades with protected openings

The other characteristics considered, shown in Plate 4.3.1(ii)-(x) are as follows:

(ii) Basal-loops *(bl)* were a defining characteristic for a group of spearheads, which could be divided into three blade forms, triangular, lanceolate and flame-shaped.

(iii) Dumpiness *(d)* was the defining characteristic of a large group of spearheads, with lanceolate or almost vestigial blades, which were exceptionally short with disproportionately wide sockets.

(iv) Openings *in blades (op)* were usually lunate but there were some rounded openings and two blades had protected openings *(o)*, evidently an early characteristic, given its associations with rapiers in three hoards (Burgess 1968, 22).

(v) Stepped *blades (st)* usually had one step, outlining the inner blade edge, but a number of blades with multiple steps *(nst)* occur.

(vi) Fillets *(f)*, where present, generally ran the length of the blade on either side of the midrib but some, especially on basal-looped blades, were associated with channels in the blade and a few were on the crest of the midrib.

(vii) Channels *(gr)*, where present, were largely confined to basal-looped spearheads and some also had fillets at the outer edge of the channel.

(viii) Hollow-casting *(h)* varied from the presence of a small hollow area at either side of the rounded midrib to blades which were completely hollow except for the cutting edge, many of which had no actual midrib. This characteristic was particularly difficult to assess since, in the case of partially hollow blades, any obstruction to the socket could mask it completely and, even when no obstruction was present, the extent of hollow casting was difficult to see unless the blade was broken.

(ix) Straight-bases *(s)*, where the blade meets the socket at right angles, have been cited as precursors of barbed spearheads (Burgess *et al.* 1972, 224).

(x) Midrib *shape* was either angular, basically a triangle or triangle with rounded apex in cross section, or round, a semi circle or semi ellipse in cross section. Those hollow blades with no midrib had elliptic or lozengic cross sections.

4.3.1.2 Analyses of Characteristics

All characteristics were tested both for correlations and for regional differences. Several of the characteristics were either so uncommon or so closely associated with another that statistical testing was impossible. Most characteristics were tested for significant differences from the overall population proportions using the Chi-squared test with 5% significance level. Those results which showed significant difference are set out in Appendix 1. All differences described as significant in what follows were shown to be statistically significant at the 5% significance level

The population data for blade shape are summarised in Table 4.3.1(i) and the results of testing for regional differences in this and the other characteristics are summarised below:

***Lanceolate** blades:* There was no significant regionality in the distribution of this blade shape.

***Flame-shaped** blades:* The proportions of blades of this shape were significantly high in Scotland and in Scotland and East Anglia combined and low elsewhere.

***Ogival** blades:* There was no significant regionality in the distribution of this blade shape.

***Barbed** blades:* These had a skewed distribution with a very high proportion coming from the West, although an expected value of less than 5 precluded significance testing, and significantly low proportions present in Scotland and in East Anglia. This reflects closely the distribution of known examples (Burgess *et al.* 1972, 220-222)

***Triangular** blades*: All triangular blades were either basal-looped or had protected openings. There was no significant regionality in the distribution of this blade shape.

***Basal-loops**:* The data for the basal-looped spearheads are summarised in Table 4.3.1(ii). There was no significant regional bias in the presence of basal loops. Unfortunately the distribution of the sub-groups, based on blade shape, could not be tested for regionality although the proportion of lanceolate basal-looped spearheads in East Anglia did seem to be low. The basal-looped spearheads were significantly different from the overall population when subdivided into basic outline shape. Almost all the triangular blades seen were basal-looped and there were no barbed or ogival blades represented. The proportion of flame-shaped blades, among the basal-looped examples, was higher than expected, though significance could not be established, and the proportion with lanceolate outline was significantly lower than in the rest of the population.

Dumpiness: The data for dumpy spearheads are summarised in Table 4.3.1(iii). There were no dumpy spearheads present in Scotland or in the West and their absence from Scotland and from Scotland and the West combined was statistically significant. The proportion in the South East was over twice that expected which was also significant. All of the spearheads with this characteristic were lanceolate in blade outline and this, again, was significant.

Openings in blades: The data for spearheads with blade openings are summarised in Table 4.3.1(iv). Regionality was significant in the distribution of spearheads with openings, whether considering only those with lunate openings or those with openings of all shapes. Openings were significantly disproportionately common in Scotland and the West combined while being significantly uncommon in East Anglia. When considering the blade shapes of spearheads with openings, it was evident that the proportion with lanceolate blades was significantly lower than expected. The proportion with flame-shaped blades was higher than expected, though this was in part due to the need, in otherwise narrow blades, to allow a bulge in outline towards the blade base to accommodate a lunate opening.

Stepped blades: The data for spearheads with stepped blades are summarised in Table 4.3.1(v). There was no significant difference in the proportion of stepped blades from that expected on a regional basis. However, when blades with multiple steps were excluded from consideration the proportion of single stepped blades in the South East was significantly lower than expected, while the percentage in East Anglia remained relatively high. There were no stepped triangular or barbed blades and only one stepped ogival blade, of the type with less pronounced outline. Thus the tendency for stepped bades to possess a lanceolate outline was statistically significant. Indeed all three flame-shaped blades possessing steps also had lunate openings.

Fillets: The data for spearheads with fillets are summarised in Table 4.3.1(vi) and the data for basal-looped spearheads with fillets are summarised in Table 4.3.1(vii). The presence of fillets was significantly regional in nature. The proportions in Scotland and in Scotland and the West combined were significantly high while those in East Anglia and in East Anglia and the South East combined were significantly low. This applied when considering fillets in general as well as when considering only fillet defined midribs. It also applied whether or not basal-looped spearheads were included. The presence of fillet defined midribs was significantly associated with lanceolate blades, only three flame-shaped, all with lunate openings, and one ogival blade had this feature. Other fillets were associated more with flame-shaped and basal-looped blades.

Channels: The data for spearheads with channeled blades are summarised in Table 4.3.1(viii). There was no significant regionality in the distribution of blades with channels. The vast majority of channeled blades were also basal-looped and, when considering these, there seemed to be some tendency for channels to appear disproportionately on the triangular bladed variety but this was not statistically significant.

Hollow-casting: The data for hollow-cast spearheads are summarised in Table 4.3.1(ix). Hollow-cast spearhead blades were also differentially distributed across the regions. This characteristic was present in a significantly larger than expected number of East Anglian spearheads and was significantly less common than expected in the West and the South East. There were no ogival or triangular hollow-cast blades among those examined and this was, in both cases, statistically significant. There were fewer flame-shaped and significantly more barbed and lanceolate hollow-cast blades than expected.

Straight-bases: The data for straight-based spearheads are summarised in Table 4.3.1(x). There was no significant regionality in the distribution of straight-based spearheads. The distribution of blade shapes in which this feature appeared was very significantly skewed towards the triangular basal-looped variety, where the number was over eight times that expected.

Midrib shape: The regional distribution of midrib shapes is summarised in Table 4.3.1(xi) and the midrib shape data for the various blade shapes are summarised in Table 4.3.1(xii). The regional distribution of the dominant group of spearheads with round midribs was close to that of the population as a whole. However the spearheads with angular midribs were significantly under-represented in the West. Spearheads without midrib were significantly uncommon in Scotland and the South East. The very high proportion of such spearheads in the West was a result of the high proportion of barbed spearheads in that region. Angular midribs were significantly over-represented on spearheads with flame-shaped and triangular blades and significantly under-represented on those with all other blade shapes and on those with lanceolate blades considered separately. Round midribs were significantly under-represented on spearheads with barbed, flame-shaped and triangular blades and over-represented on those with lanceolate and, especially, ogival blades. The blades without midrib were only found on spearheads with barbed, flame-shaped and lanceolate outlines and were over-represented on the first and under-represented on the last.

4.3.1.3 Spearhead Groups

Protected-opening and basal-looped spearheads, given their obvious morphological difference and early dating (Needham *et al.* 1998) have been treated as a separate group.

An initial division of the pegged spearheads according to blade shape is illustrated in Figure 4.3.1(i) This shows the dominance of the lanceolate blade shape overall, although the barbed blades formed a large percentage of the numerically small Western group.

The categorisation was extended by subdividing into plain and complex (c) types; the latter group included all spearheads with one or more of the characteristics listed above, apart, of course, from midrib shape. This was further refined by treating the 'dumpy' lanceolate blades (ld) as a separate group. The distribution of these groups is shown in Table 4.3.1(xiii) and illustrated graphically in Figure 4.3.1(ii). The total lack of 'dumpy' spearheads in Scotland, as mentioned above, is highly significant.

The small group of basal-looped blades were subdivided according to their blade shape, as shown in Figure 4.3.1(iii). Further subdivision was made according to the additional characteristics exhibited, most commonly channeled blades and fillets. The distribution of these groups of basal-looped spearheads is summarised in Table 4.3.1(xiv).

The complex pegged spearheads could readily be divided into groups dependent on the characteristics they possessed and, as was shown above, a number of these characteristics appeared to have some regional significance. These detailed spearhead groups are denoted by labels formed from the short versions of the blade shape followed by the various characteristics as defined in Chapter 4.3.1.1 above.

The distribution of the complex flame-shaped spearheads groups based on the presence of one or more major characteristics is shown in Table 4.3.1(xv).

The sub-division of the large group of complex lanceolate spearheads into groups based on the presence of one or more major characteristics is shown in Table 4.3.1(xvi) and Figure 4.3.1(iv). This shows the predominance of hollow cast (h) and stepped blades (st) among East Anglian and Scottish spearheads examined. Fillet definition (f) seems to have been especially popular in the West, while multiple stepped spearheads (nst) were largely confined to the South East, reflecting the fact that most examples were found within the Blackmoor hoard (Colquhoun 1979).

Obviously a number of the subgroups are so small that further statistical analysis would be pointless but the diversity and individuality exhibited by the most complex spearheads is readily appreciated from the tables.

4.3.1.4 Dimensional Analyses

Figure 4.3.1(v) shows the major blade dimensions for the main groups of spearheads. This shows clearly the tendency for most complex spearheads to be larger than the plain spearheads with the same blade shape. It also demonstrates the narrow range of dimensions for the group of dumpy lanceolate blades and the group of ogival, Watford type, spearheads.

Figures 4.3.1(vi)-(viii) show the major blade dimensions for those spearheads sufficiently complete for consideration in each of the main groups of complex spearheads, i.e. the basal-looped, flame-shaped complex and lanceolate complex blades, subdivided according to characteristics. Inspection of the graphs shows clearly that the most complex spearheads tend also to be the largest. It is also evident that the least obviously visual of the 'characteristics', i.e. hollow-casting, is not generally associated with large dimensions unless other characteristics are present.

The plain pegged spearheads could not be further differentiated except by resort to analysis of the distribution of their dimensions, which had already played a considerable part in isolating the group of dumpy lanceolate spearheads. As there were relatively few plain flame-shaped spearheads, statistical analyses were confined to those with lanceolate blades.

Plain Lanceolate Spearheads

Graphs of the blade length and maximum width of those plain lanceolate spearheads sufficiently complete to be considered are shown in Figure 4.3.1(ix). It is clear that the distributions for spearheads from the four regions considered overlap substantially but that there is some degree of regional variation. It is also clear that the South Eastern group divides into two groups, one small group of very large spearheads and a large group which falls within much the same dimensional range as those from other regions.

The dimensional data for the plain lanceolate spearheads are summarised in Table 4.3.1(xvii). The figures for the South Eastern spearheads are shown both including and excluding the group of very long spearheads. All of the means were tested pairwise for equality using Student's t-distribution (Shennan 1988, 306). This test requires that the data for each of the groups to be compared form a normal distribution and measures of skewness and kurtosis for each of the groups were examined in order to ensure that they fell within a range compatible with the assumption of normality. All differences described as significant in what follows were shown by the test to be statistically significant at the 5% significance level

There were significant differences in mean length between East Anglia and all other regions, between Scotland and the South East and between the South East and the West. The East Anglian spearheads were on average shorter than those from other regions. The mean length of South Eastern spearheads was longer than that of other regions when the group of very large South Eastern spearheads was included but when they were excluded only the East Anglian mean length was significantly lower than that of each of the other regions.

Graphs of the two ratios used to define the shape of the lanceolate blade, maximum blade width to blade length and distance from point of maximum blade width to blade base divided by blade length, are shown on Figure 4.3.1(x). The underlying data are summarised in Table 4.3.1(xvii).

The mean relative width of the East Anglian blades was significantly greater than that shown by South Eastern and Scottish blades and the South Eastern mean relative width was significantly lower than that of spearheads.from Scotland, but only when the very long blades were included. Although the mean relative width of the Western blades fell between the Scottish and South Eastern figures, no significant differences could be established for this small group.

The second ratio reflects the relative symmetry of the blade about the plane perpendicular to the midrib. The mean of the ratio for the Scottish spearheads was significantly higher than that for the blades from East Anglia and from the South East. The mean for the Western blades was above that for all other regions but, once again, this difference could not be shown to be significant.

The mean ratios of socket length to blade length are shown in Table 4.3.1(xvii). Although the mean ratios for spearheads from East Anglia and the South East were lower than those for the other two regions the differences were not statistically significant.

The two final dimensions considered, socket diameter and socket wall thickness, were capable of being assessed from relatively incomplete spearheads, provided that the socket was largely complete. The data for these are summarised in Table 4.3.1(xvii).

The mean socket diameter was remarkably consistent from region to region, while, on average, socket walls were significantly thicker in the West than in all other regions.

Complex Lanceolate Spearheads

Although most of the groups defined by their characteristics were too small for numerical analysis of dimensions of the spearheads to be meaningful, some statistically significant regional differences did emerge for some of the larger groups.

Hollow cast lanceolate blades were closest to the plain lanceolate blades in the regional analyses of their dimensions, although there were no Western examples. The relevant data are summarised in Table 4.3.1(xviii).

There were statistically significant differences in mean length between spearheads from East Anglia and Scotland and those from East Anglia and the South East, with the East

Anglian blades again being significantly shorter. In this case there was a statistically significant difference in relative socket lengths with the Scottish figure exceeding the East Anglian. The mean relative width was also significantly greater in East Anglia than in the South East and the Scottish blades were, on average, significantly closer to symmetry than those from either East Anglia or the South East.

Hollow cast lanceolate blades with a single step, the data for which are summarised in Table 4.3.1(xix), also proved to be significantly more symmetrical in Scotland than in East Anglia.

Other Spearhead Groups

The ogival blades, as can be seen from Figure 4.3.1(v) fall within a relatively small range of dimensions. These are summarised in Table 4.3.1(xx). The only statistically significant differences were in overall length where the Scottish blades were significantly longer on average than the South Eastern and East Anglian blades.

Although there were very few barbed blades sufficiently complete for consideration, the differences between those which were proved very substantial, reflecting the fact that the Western examples examined were of Burgess' Type III and the South Eastern were of Type II (Burgess *et al.* 1972, 220). The data are summarised in Table 4.3.1(xxi). The South Eastern blades were significantly longer and narrower than those from the West and the relative length of their sockets was significantly lower.

4.3.1.5 Spearhead Typology - Summary

While it is feasible to group the spearheads according to their morphology and size, the number of possible groupings is large. Clearly the numbers of each type of very complex spearhead are small but there are many different ways in which these can be grouped at a less refined level. The approach followed above gives priority to obvious differences in appearance and, to a large extent, these did correlate with differences in dimensions. Certain factors appear to have been largely regional in their incidence while others were not geographically differentiated and the implications of this will require further consideration.

One factor examined, hollow-casting, owed little to obvious visual impact and, while showing some regionality in its incidence, appeared to have only very slight impact dimensionally. A grouping which attaches importance to this factor would therefore be more likely to focus on the making, and perhaps the use, of the spears, than on any broader symbolic interpretation applicable to society in general.

The lack of differentiation among the plain spearheads continues to present problems and it may be that a much more detailed examination of minor morphological differences could yield more information. In particular examination of the relative width of the blade edge and the positioning of peg holes might help to pinpoint regional or chronological differences within this group.

4.3.2 Spearhead Design

It is clear from the wide variety of spearhead types that at least some of those who designed the spearheads worked with more than utility in mind. While most of the plain spearheads could be held to be designed solely for stabbing or throwing and several of the characteristics of the more complex spearheads could have some utility as well as being visually distinctive, there is little obvious utility value in a number of the features noted, such as the presence of fillets, straight blade bases and multiple steps, and even less in the combination thereof in spearheads of exaggerated size.

Characteristics which could have been designed to be useful include those which decrease the weight of the spearhead, such as the presence of blade openings and hollow-casting. This would of course only be a real advantage if the spears were to be thrown, although throwing spears could easily be used for stabbing as well. Dumpy spearheads are differentiated by their very small size as well as their squat shape and appear to have a fairly uniform design, which would effectively put a 'winged' metal tip on a standard shaft.

The means of securing the shaft to the spearhead must have been a prime utilitarian design consideration. The move from basal-loops to securing by means of pegs is clear from a number of basal-looped examples which also possess pegholes. Using loops to secure the spearhead firmly may have been advantageous if pegs had to be so wide as to weaken the shaft or pegs could not be made accurately to fit the holes in the socket.

The security of the join depends not only on tying on via loops or openings or pinning through peg holes but also on the extent to which the shaft penetrates the blade. The mean ratio of internal socket length to overall length for the basal-looped spearheads, at 0.63, is significantly lower than that for all the lanceolate bladed spearhead groups, which range from a mean of 0.71 to 0.76, and the ogival, Watford type, spearheads, mean 0.79. The flame-shaped blade groups have a mean of 0.67 and the very few barbed and protected-opening spearheads had means for this ratio of 0.52. These ratios may in part be explained by the fact that, apart from the barbed spearheads, the groups with a low ratio all tend to have a greater mean length than the others but it remains likely that those spearheads with a low ratio would be less securely hafted than those where the socket continued further down the length of the blade.

The presence of openings may have been required for extra security of hafting, indeed the protected-opening spearheads did not have peg holes, but could also be intended to lighten the spearhead, to provide means of attachment for items intended to decorate or identify or simply to be decorative or symbolic in themselves. A combination of any or all of these may have been the intention of the pattern maker.

The barbed spearheads, with their shallow sockets, barbs and large metal pins present problems if viewed as a design for utility and could well have been designed 'purely for ceremonial and ritual purposes' (Burgess *et al.* 1972, 235). The barbs were clearly not designed to penetrate and retrieve during warfare in the manner of harpoons used in fishing, given the extent of the penetration required and the futility of retrieving enemy corpses. They may have had a function in setting fire to buildings or crop stores since the blade would readily penetrate material such as thatch and any burning material attached to the massive pins would be held fast against removal.

Fillets would also have formed a part of the pattern design. They may have served a purpose in terms of casting in that they do provide a wider channel for the metal, by effectively smoothing sharp angled junctions where casting faults are likely to occur, but the characteristic's infrequent presence renders such a practical proposition less likely. They were most probably a decorative, or possibly symbolic, feature.

Incised decoration is a relatively rare feature, which occurs on 24 spearheads, representing just over 5% of those considered. Most of the decoration is only on the socket, only 4 spearheads have blade decoration, in addition to that on the socket, and these comprise 1 lanceolate basal-looped blade, 2 flame-shaped complex blades (1 channeled and 1 with lunate openings) and 1 lanceolate fillet-defined stepped blade. The remaining 20 spearheads, with socket decoration only, were made up of 10 ogival blades, 6 plain lanceolate blades, 2 channeled lanceolate basal-looped blades and 2 lanceolate stepped blades, one of which had lunate openings. Clearly such decoration was significantly, indeed massively, over-represented on the ogival, Watford type, blades.

Since the numbers were small, there was no statistically significant regional bias in the distribution of decorated spearheads but the South East did seem to be favoured at the expense of all the other regions. Considering the ogival spearheads as a group, this difference was much less marked.

The designs incised consisted mainly of simple rings around the socket, some have triangular patterns or concentric semi-circular lines. Examples of socket decoration are shown in Plate 4.3.2. Such patterns are only obvious on fairly close inspection and, if they were not purely decorative, any symbolic role they played would therefore not have been via public display. While such decoration could easily be added at any stage of the spearheads' history, it seems probable, given the extreme bias towards one type of spear blade, that it did form part of the design process and that, for whatever reason, spears of this type were expected to be decorated at some stage of their existence.

4.3.3 Spearhead Manufacture

The casting of socketed spearheads could, in some cases, have been even more difficult than casting swords. The very long spearheads would require the same quality of mould as a sword with the added problem of suspending a core and holding it accurately in place to form the socket. Since the casting of small and medium length spearheads requires very much the same techniques as casting socketed axes, it is plausible that less skilled metal workers could have produced both, while the long and more complex spearheads were made by those who produced swords. As shown in Chapter 2, not only was the finishing applied to spearhead edges a lot less than for swords, where hardening is essential, but the quality of the casting also seemed to be a lot more variable.

As was done with the swords examined, the casting quality of spearheads was initially assessed by visual examination and graded in the range 1 to 5. The grades were then amalgamated to produce three grades, 'good', 'fair' and 'poor' and the results are summarised in Table 4.3.3(i). Approximately 10% of the spearheads, some 47 by number, could not be assessed, due to burning or corrosion.

The percentage of spearheads showing poor quality was, at 20%, substantially higher than the equivalent 6% for swords. This bears out the findings of the metallographic analyses.

The distribution of the grades among the various spearhead types did show some statistically significant variation using a Chi-squared test with 5% significance level. All differences described as significant in what follows were shown to be statistically significant at the 5% significance level and the relevant Chi-squared statistics are shown in Appendix 1.

The basal-looped group had fewer good quality but significantly more fair quality spearheads. The barbed group had fewer good and significantly more poor quality spearheads than expected while the ogival group had a significantly higher proportion of good quality and a lower proportion of poor quality spearheads than the population as a whole. This underlines the special nature of this spearhead type noted from the frequent appearance of incised decoration thereon.

The regional distribution was also statistically significant with the South East having significantly more good and significantly fewer poor quality spearheads and the West having significantly fewer good and significantly more poor quality than expected. The latter reflects the similar pattern seen among the barbed spearheads which were most strongly represented in the West.

4.3.4 Spearhead Use

Clearly the practical use of spears in warfare includes both their use as throwing weapons and as stabbing weapons. In both cases the tip is the most likely area to suffer damage and, unlike swords, damage to the edges is relatively unlikely. However, even damage to the tip depends on the material against which it strikes. As was shown in the experimental work on blade edges described in Chapter 3 above, impact with hard wood, toughened leather and even bone left little trace on the metal edge and would be expected to have a similar effect on a spear tip which penetrated them. Some degree of damage would be expected to be obvious if the tip failed to penetrate or if it were forced or deflected at an awkward angle. Two examples of quite substantial tip damage are shown in Plate 4.3.4(i). Spears used for throwing are likely to have experienced less damage as they are more likely merely to have fallen to earth than to have been forced against a hard surface.

The other area most likely to show damage is the socket, though this type of damage should be confined to spears used in stabbing mode. Pressure on the shaft could lead to cracking or breakage around the pegholes while any angled pressure could lead to cracking or breaks at the socket mouth. Some examples are shown in Plate 4.3.4(ii). Similar damage could be caused by the forcible removal of the shaft prior to deposition and there seems to be no obvious means to differentiate between the two causes.

Clearly during use spears may suffer damage from shields and other weapons, such as swords or axes, which can be used to deflect a stabbing spear. Thus it is to be expected that some edges and midribs show distortion. However, where such distortion is major it is more likely to show deliberate destruction of the spear than battle damage; a series of substantial distortions and tears in the edge require delivery of a series of heavy blows in the one plane unlikely to occur during fighting while a large dent or gash in the midrib probably requires prior removal of the wooden shaft. There is of course the possibility that an element of post depositional damage, especially plough damage, is sufficiently old to have been mistaken for ancient damage. This too is likely to be major in nature, resulting in breakage or midrib damage.

The data for tip damage are summarised in Table 4.3.4(i). The proportions showing damage were tested for significant differences from population proportions using the Chi-squared distribution with 5% significance level. All differences described as significant in what follows were shown to be statistically significant at the 5% significance level and the relevant Chi-squared statistics are shown in Appendix 1.

When examined on a regional basis there are significant differences. When tips which are substantially missing are excluded the South East stands out as having significantly more undamaged tips and fewer damaged tips than would be expected from the population statistics, while all the other regions have somewhat more damaged tips and fewer undamaged. When those spearheads with missing tips are combined with those whose tips are damaged the same pattern is even more evident for the South East and the figures for the Western region become highly significant with the actual number of undamaged tips being less than half the expected number. The fact that the addition of the broken tips makes very little difference to the relative proportions for East Anglia, where plough damage is most likely, argues against a high proportion of the spearheads having had tips damaged after deposition.

When the data are assessed according to spearhead type, variation from the population proportions are much less marked although there is a tendency for the dumpy lanceolate spearheads to have significantly more undamaged and fewer damaged examples than expected. When the spearheads with missing tips are combined with those with damaged tips, the basal-looped, the ogival type and the dumpy spearheads have a significantly higher proportion of undamaged and a lower proportion of damaged or missing tips than the population as a whole, while the plain lanceolate spearheads have significantly more damaged or missing tips than the overall population.

The relationship between blade length and tip damage was investigated for those spearheads with complete blades. Overall there was little difference between the proportions of spears with tip damage in the groups with below and above median blade length. Even in the one group where the proportions did appear to differ, the plain lanceolate blades, the difference was not statistically significant. However, none of the very long South Eastern spearheads showed any tip damage which indicates that there were different factors applying to them, since their long narrow tips are more fragile than most and should therefore have experienced more visible damage than others if used in a similar fashion.

The data for socket damage are summarised in Table 4.3.4(ii). The proportions showing damage were tested for significant differences from population proportions using the Chi-squared distribution with 5% significance level. All differences described as significant in what follows were shown to be statistically significant at the 5% significance level and the relevant Chi-squared statistics are shown in Appendix 1.

The numbers of undamaged sockets in the South East and of damaged sockets in Scotland are significantly high, when spearheads with the socket missing are excluded. When they are included and treated as damaged, the South Eastern proportion of undamaged sockets remains significantly high, while the Scottish and Western proportions of damaged sockets are significantly high.

The proportions of damaged and undamaged sockets according to type show no statistically significant differences, when spearheads with missing sockets are excluded from the data, but when they are included, and treated as damaged, the previous pattern is strengthened to the extent that the numbers of undamaged sockets for the dumpy and ogival lanceolate spearheads and the number of damaged sockets for the plain lanceolate spearheads are all significantly higher than expected.

Clearly the results are only indicative of the effects of actual use in warfare, given that the damage cannot definitively be tied to such activity. The high proportion of spearheads showing socket damage, approximately 40% excluding those with missing sockets and 56% when the latter are also treated as 'damaged', contrasts with the lower proportion, 17%, showing tip damage, though the inclusion of those with missing tips brings that proportion up to 36%. It would seem reasonable to assume that some of the socket damage is due to non-use damage, either before or after deposition and that the proportions showing tip damage reflect more closely the incidence of use damage.

4.3.5 Spears - Summary

Spearhead Typology and Design

Obviously the typological variation among spearheads is much wider than that of swords, reflecting not only changes over time and regional preferences but also the wider range of ways in which spearheads may be used. Although some spearheads, particularly the plain lanceolate type, are problematic, there is already some indication of the place within the chronological sequence of certain spearhead types. The basal-looped are early and often feature angular midribs, which are strongly correlated with flame shaped and triangular blades, while the barbed and ogival spearheads, which are generally found with Ewart Park or Carp's Tongue swords, are later.

The combination of the presence within spearhead sockets of organic shaft remains which can be dated and the wide variety of size shape and characteristics within the spearhead population could mean that, in the future, the chronological position of spearhead types may be more precisely defined. Indeed it may well be that, within certain regions, they have the potential to provide the key to dating other artefacts.

Regional differences in spearhead populations included a propensity for flame shaped blades to be Scottish or East Anglian, for barbed spearheads to be Western or South Eastern and for dumpy spearheads to be absent from Scotland and the West. Blade openings and fillets were most common in Scotland and the West, with fillets being most often associated with a lanceolate blade outline. Single stepped spearheads and hollow cast spearheads, the two characteristics being often combined, were disproportionately common in East Anglia. Hollow casting was largely confined to lanceolate and barbed blades.

Quantitative analysis showed clearly that complex spearheads tended to be larger than plain ones but that hollow cast spearheads which were otherwise plain did not tend to be larger than their plain counterparts. There were some significant regional differences in population statistics for the plain lanceolate and the plain lanceolate hollow cast groups, with those from East Anglia being relatively short bladed and relatively wide while the widest point of the Scottish and Western blades was relatively closer to the tip than in East Anglia or the South East. The Western plain lanceolate spearheads were relatively thick walled, which may have been functionally beneficial or may indicate inferior manufacturing technique. Barbed spearheads could readily be quantitatively differentiated into the short, wide bladed and the long narrow bladed types, already identified (Burgess *et al.* 1972). Scottish ogival spearheads were longer than those elsewhere but the ogival and dumpy spearheads displayed a very narrow range of dimensions.

The dumpy spearheads were clearly the best designed for throwing, although stabbing use is quite feasible. The barbed spearheads with their very shallow sockets could have been used to anchor flaming material firmly to thatch or wattle, in which case the weakness of the shaft joint might even have been advantageous. The largest versions might well have been used for display. Fillets, while performing a useful function from a manufacturing perspective, appear mainly designed to be attractive while incised decoration, less rare than on swords, was overwhelmingly confined to the ogival spearheads whose abrupt points also indicate some specialised function which required that any puncture wound be wide and relatively shallow.

Spearhead Manufacture

The proportion of spearheads whose quality could be described as poor, approximately one fifth, was greatly in excess of that for swords which is an indication that some at least were not made with the same care and expertise. While it is possible that such poor quality spearhead were made by the skilled sword makers and the low quality was tolerated for spears but not swords, it is more likely that they were made by those with less knowledge and skill, possibly 'apprentice' sword makers in specialist 'workshops' or less specialised metal workers who could produce basic tools on an ad hoc basis.

The earliest type, the basal-looped, tended to be of fair rather than good quality. Barbed spearheads tended to be of poor quality and ogival spearheads were generally of good quality manufacture, in keeping with their tendency to be decorated. The South East tended to have a higher proportion of good quality spearheads than other regions.

Spearhead Use

Although damage caused by use in combat cannot be differentiated from that caused during use in hunting the tendencies for the spearheads to exhibit tip and socket damage have been taken as, at least in part, indicative of combat use. There were decided differences in the incidence of such damage with the plain lanceolate spearheads having a relatively low proportion of undamaged examples while the ogival and dumpy groups exhibited high proportions of undamaged spearheads. Regional differences also existed with the South East having a tendency to deposit undamaged spearheads when compared with other regions, particularly Scotland and the West.

The results would support an interpretation of the dumpy spearheads being generally used as throwing spears and the plain lanceolate spearheads as being the type most frequently used as stabbing spears. The relative lack of damage shown by the Watford type spearheads, taken with their decided tendency to have decorated sockets, denotes them as being in some manner 'special', possibly used in ritual or kept as prestigious personal possessions, and less frequently used in a practical manner prior to deposition. The very long South Eastern spearheads also show much less tip damage than would be expected, given their relative fragility, and are thus also likely to have performed a non-practical role, but their excessive size indicates that this role was probably more in direct public display than that of the ogival (Watford) type.

5 Warfare, Weapon Deposition and Social Contexts

As stated in the introduction to this study, Chapter 1.1 above, the ultimate aim of this research is to assist in the study and understanding of the people who produced used and deposited the weapons. Some assessment of the role which weaponry played is therefore required. The weapons themselves provide information on the practices of warfare and the procedures and rituals surrounding the 'decommissioning' and deposition of weapons. In what follows these subjects are discussed in some detail before moving on to consider the possible implications of the evidence examined for the social context of the period.

The information is frequently obscure and interpretations require not only resource to historical and ethnographic analogues but also to considerable exercise of imagination, as advocated by Bradley (1993, 133). None of the resulting interpretations can be considered either correct or complete but all should at least comply with the material evidence available and acknowledge the alternative possibilities which undoubtedly exist.

5.1 Conflict and Warfare

The subjects of conflict and warfare are most frequently tackled from an historical viewpoint although there have, as outlined in Chapter 1.3.1 above, been numerous ethnographic studies of 'primitive' societies which include examination of such topics. Some attributes of the conduct of warfare, particularly the social aspects, are extremely difficult to reconstruct from the evidence provided by the weapons and extrapolation from and comparison with the roles and conduct of warfare in better known societies can help provide a basis for interpretation.

5.1.1 Varieties of Warfare and their Characteristics

There are numerous ethnographic, historical and mythical examples of conflict resolution by means of physical, generally armed, contests between individuals or small teams selected to represent groups of people or individual rulers. Many such contests are reputed to have had a substantial ritual content, including pre-fight vigils, purification rites, drug taking, use of 'magic' symbols and weapons, the donning of special clothing or armour and specific death rituals.

The medieval chivalric tradition of 'champions' and tournaments in Western Europe and the series of heroic conflicts described by Homer in the Iliad epitomise traditions of contests between individual 'champions', although these individuals invariably came from larger groups of warriors. The participants in these contests appear to have been well trained in martial arts and either to have been entirely supported by a powerful individual or, although capable of being sustained by virtue of their own possessions, to have been an ally of or subordinate to another powerful individual. However, in less stratified societies the extent of martial training may well be less onerous and such contests sufficiently infrequent as to permit that the participants support themselves in the same manner as other group members. Indeed the requirement to participate may not depend at all on skill or inclination but on factors such as age, membership of a certain family or caste, 'debts' owed to society or individuals. It may even simply to be an obligation which all, at some time, are expected to fulfil.

A lack of skill is much less important when the contest does not require the death or even substantial injury of the opponent but is largely a ritual show of aggression and ceases before there is any serious bloodshed, e.g. a Yanomamo 'chest pounding' (Chagnon 1977) or a typical New Guinea 'nothing fight' (Rappaport 1968). These contests are reputed to have often provided a means by which the strengths of the opponents and their alliances could be assessed without actual violence and to have led to settlements of differences, often negotiated at the behest of interested allies, without loss of life or of face. Provided that the outcome was accepted by all concerned no escalation needed to occur and the result was defined by social rules rather than the demise of the opponent.

However, in all such contests there is an inherent probability of escalation and this escalation may involve a change in the permitted weaponry. The Maring and Mae Enga of New Guinea banned the use of their most lethal weapons, those for hand-to-hand combat, in the 'nothing' fight but permitted their use in the 'true' fight (Rappaport 1968, Meggitt 1977). Thus while fatalities were rare, but not unknown, in the 'nothing' fight, fought with large shields, bows and unfletched arrows, they were fairly frequent in the 'true' or 'axe' fight, fought with axes, stabbing and throwing spears. The ritual procedures which had to take place were also very different with the majority in the latter case being involved with death (Rappaport 1968).

Similarly there are examples of a long tradition of raiding between groups, such as that which was endemic in the Scottish borders until the seventeenth century, intended for theft only, wherein the participants often avoid direct conflict by stealth but are armed and prepared to fight if necessary. The aims of such hostilities may not be confined solely to the acquisition of animals or goods; the seventeenth century Iroquois confederacy for example used captives acquired in raids to replace population lost to European diseases (Abler 1992) and the acquisition of females, without the expense of a 'bride price', has, in a great many societies, been a prime motive for raiding. The talents honed during raiding activities may well be harnessed for particular purposes, such as the protection of personages or property in transit through potentially hostile territory, either on a permanent or a one-off basis.

Raiding groups, often consisting of younger males, such as the Samburu 'age sets' (Spencer 1965), and the 'young bloods' of the Blackfoot Indians (Ewers 1958) may assert themselves within their own groups by means of the hostilities involved in stock raids. Such raids could also give rise to an ambivalent response from the group elders, involving official disapproval, largely for the purposes of peace making and re-establishing control, combined with a certain amount of unofficial approbation, especially if direct relatives had appeared to advantage.

All of these types of violent action involve directly only a minority of the population, generally younger males, but all are socially sanctioned activities either actively supported or at least tolerated by the entire group and are generally expected to be advantageous to the group as a whole as well as to the individual participants. Direct retribution for such acts is very likely to be detrimental to non-combatant individuals, who may be killed, captured or lose property, while negotiated reparations will almost always involve a loss to the entire group and not just the combatants. The expected benefits, whether material or spiritual, must therefore be sufficient to compensate the group for the risks involved.

A pattern of such activities which continues at a relatively low level over a considerable period indicates that no one group can gain ascendancy and maintain it for any length of time. Thus, while armed conflict may be used to settle differences, it generally takes place within a framework of 'rules' which means that it can be 'managed' in such a way as not to escalate out of control to the detriment of almost all concerned. Periods of ascendancy of one group or ruler may well be marked by a relative absence of actual conflict but the production of weapons and the training of individuals are likely to continue at the same level, albeit the activities concerned are likely to be more centralised than before.

The visible effects of such conflict are generally short term in nature, with limited destruction of property and resources and little or no perceptible change in overall activities and rituals. In effect the practice of limited warfare is accepted as an intrinsic part of life and the provision of the required weapons, fighters and the rituals concerned are not regarded as unusual or especially onerous.

This type of 'low level' intermittent warfare may be contrasted with episodes of full scale hostilities wherein the majority of the able bodied male populace is directly involved in combat. During the course of this type of warfare 'normal' life, including subsistence activity, is abandoned or dramatically curtailed and, if it is prolonged, the non-combatants, typically the majority of adult females, children and aged males, must undergo hardship. Under such circumstances it is possible for certain groups to undertake unaccustomed roles, such as those performed by the 'land girls' and female plane makers of the World War II. In certain cases, such as when a group's territory is invaded, or when the prevailing social mores permit, the active participants may include females or even children, as was the case with those who fought with the Maquis in France and the Palmach in Israel during the 1940's.

The outcome of such warfare is generally extensive destruction of people, property and resources. There is almost always disruption of preceding social systems, up to and including the total replacement of certain groups in certain territories, although the replacement of one ruling elite by another leaving most of the populace disrupted but *in situ*, has historical precedents. Where full scale warfare is prolonged, not only is agricultural and industrial production curtailed and skewed towards supply of the combatants but certain rituals, especially those concerned with death and with seasonal events, are likely to be subject to change or abandonment.

Cessation of hostilities may engender a resumption of previous practices if there has been no real change in population or social structure but is likely to introduce new practices where populations or ruling elites have changed. Such changes, from an archaeological perspective, are relatively rapid but may appear to be subtle if, as is usual, hostilities have been between neighbours with similar social structures and rituals. To the people affected, however, such changes may well seem very far from minor and their symbolic significance should not be underestimated.

In addition to the presence or absence of destruction 'horizons' or changes in subsistence and ritual practices within the archaeological record, the surviving weapons will provide indications of the modes of combat for which they were designed and of how they were actually used. Skeletal remains should, if preserved, provide further evidence of both the scale and manner of combat and of which members of society were directly involved.

5.1.2 Modes of Combat in LBA Britain

The archaeological evidence in Britain suffers from a lack of skeletal remains from the period. Inurned cremation burials were common in the South and East during the preceding period but, by 1200BC, these had given way to funerary practices which have left almost no trace. Human bones or fragments thereof are found on settlement sites, in rivers and with metal deposits but Bruck (1995) has shown how few they are. She lists some 101 sites with identified human remains reported, of which only nine are inhumation burials, and the vast majority of these sites have provided only fragmentary skeletal material. Although modern rapid high temperature cremation methods leave sufficient bone intact to require reduction to powder in a cremulator, cremation which takes place over a longer period can utilise the fat within bone marrow as fuel and this effectively destroys most skeletal material (experimental work by Dr J de Haan, California Criminalistics Institute 1998, reported in the BBC's QED programme broadcast 26/8/98). It may be that such a cremation method was in use during this period. It is also quite possible the vast majority of remains were no longer inurned or inhumed but were simply scattered, resulting in the lack of funerary remains observed even in areas where soil conditions would normally permit bone preservation.

Among the few skeletal remains which do exist are the inhumed remains of two young men from Tormarton, Somerset, one of which had suffered head and spinal injuries and both of which had severe pelvic injuries from spear penetration. These were radiocarbon dated to 2927+/-90bp (BM-452) (Knight 1972), which dates calibrate to around the twelfth/eleventh centuries BC (Needham 1997, 85). Further excavation has uncovered more skeletal remains within the same linear ditch feature, some of which appear to be part of the earlier finds (Richard Osgood - pers. comm.). While these individuals obviously suffered violent deaths, the attribution of these deaths to warfare seems improbable. The number of severe injuries sustained and the mere fact of inhumation indicate a form of death whose nature is highly unusual. The evidence strongly suggests either sacrifice or a form of punishment, possibly highly ritualised. The nature of the pelvic injuries may even suggest that the motives had sexual connotations.

Despite the lack of human remains a proportion of the weaponry has survived and this provides sufficient archaeological evidence to enable some deductions to be made concerning the conduct of warfare in the Late Bronze Age.

Rapiers were supplanted by swords during the Middle Bronze Age, although, given their long thin blades and sharp points, they are probably more lethal than most swords. Since rapiers as long as swords already existed and spears could provide a longer reach than any sword, it would appear that a mere increase in reach was not the reason for the adoption of swords. An alternative explanation for swords supplanting rapiers is dependent on the differences in the manner in which the weapons are designed to be used and the context for which such designs are appropriate.

To kill an opponent with a stabbing weapon, such as a rapier, carries intrinsic disadvantages in group combat. During the attack and, if successful, while 'disengaging' the weapon, the user is open to attack from the side. Use of the blade in slashing mode or to parry the blows of others runs a high risk of breakage, particularly at the junction with the hilt. Moreover the need for accuracy is a decided liability in the confusion of battle. (Bridgford 1997b).

Such problems can be overcome by a highly disciplined force trained to act together and cover each other, such as Wellington's 'squares' at Waterloo, but such tactics, being far from natural, require a high level of training. This implies that an armed force would require prolonged periods of training as a coherent group and this is unlikely to be compatible with the sporadic and seasonal use of fighters whose main activity is agricultural. There is no evidence of such activities in the British Late Bronze Age, nor is there any historical evidence that the Roman invaders encountered this type of military behaviour even by the Late Iron Age.

Late Bronze Age swords are neither delicate nor precise. They have wide leaf shaped blades, no hand guards and balance well forward of the wrist. Many do not even have very sharp points. Their morphology betrays their function as slashing instruments. The extension of the intrinsically cast hilt to provide a continuous 'spine' to the full length of the weapon contrasts with rapiers where the organic hilt was attached to a tongue at the top of the blade. (Bridgford 1997b). Use of a rapier-like hilt attachment in slashing mode would naturally lead to breakage, as is frequently seen in early Ballintober swords (Bridgford 1997, 97).

While many weapons are more effective than slashing swords for killing people, few are as useful in a melee. Unlike rapiers, they are not at their best in single combat and, unlike axes, they have no alternative practical use. Any society which invented or adopted the slashing sword had to have already absorbed the tactics required for group combat (Bridgford 1997b). Slashing swords are more likely to disable than to kill but the disabled opponent is unlikely to take much further part in the conflict. While it is possible that, in some cases, killing of the opponent may not have been the desired end, as in the 'nothing' fights of the New Guinea highlands mentioned above, the morphology of the weapons indicates at the very least an indifference as to the opponent's fate. Since a single blow on any vulnerable area can easily be lethal, the level of 'accidental' fatalities is likely to be incompatible with a desire to keep hostilities at a low level.

Detailed examination of the extent and type of edge damage on the sword blades, as discussed in Chapter 4.2.4 above and comparison with the damage caused during experiments, described in Chapter 3, has shown that the majority bear some signs of damage consistent with blade on blade impact. This contradicts assertions such as: 'In pre-Roman times weapons were probably more to do with status and prestige, than something as ill-considered and wasteful, as fighting. They were more like the dress swords worn by officers in the British Army today; readily identifiable indications of rank and status.' (Pryor 1998, 135). While there is no doubt a good case to be made for weapons as rank indicators this in no way precludes their use as weapons and the 'analogy' with 'dress swords' does rather ignore the fact that British army swords were standard, and much used, weapons for centuries before the adoption of firearms 'relegated' them to the level of 'fancy dress'.

There is no obvious reason why the people who lived in Britain before the Romans arrived should, of all societies known to mankind, have been one of the tiny minority (only a few religious groups, such as Quakers, generally living within otherwise relatively violent societies, spring to mind) to eschew all fighting as 'ill-considered and wasteful'. On the evidence provided by the weapons themselves it must be concluded that most swords were actually used, hand to hand, and, given their design, that they were most likely to have been used in group combat. This theory is, to some extent, backed up by the conclusion (Avery 1993) that most early defensive constructions on hillfort sites were designed to withstand attack by sword and/or spear wielding 'infantry'.

The use of spears is more ambiguous as many could easily have been used in hunting animals as well as in combat. Moreover the spear can be used as a projectile weapon or as a stabbing weapon. The fact that the point is most likely to have penetrated organic material means that, provided it was suitably manufactured, there is a high probability, as with the experimental sword edges, that no visible damage was caused. In the case of use as a stabbing weapon there is a possibility of damage to the relatively thin metal of the socket and midrib from the forcing of the shaft deeper into the weapon.

A large number of the spearheads examined had damage to the socket and midrib which may well indicate use in stabbing mode. Where still present the tip was usually somewhat blunted and quite frequently actually damaged. Although damage to the tip as a result of combat use is highly likely there is no way in which the cause of damage can be securely attributed to such a use.

The wide variety of sizes of spearhead is most likely to reflect the variety of uses to which they were put. Most are rather heavy for projectile use and it seems unlikely, given the high probability of loss, that they were regularly used in such a manner. However, the smaller spearheads, in particular the rather 'dumpy' variety which appear in quite large numbers in several Late Bronze Age hoards (e.g. Wilburton and Blackmoor), may have been used thus. Hollow-casting, most obvious in the Wilburton and Blackmoor types, was probably designed to reduce weight but is also used, along with the casting benefits conferred by the addition of lead to the alloy, to produce intricate profiles and attractive looking weapons.

The microstructures of the spearheads show that the majority, like swords, were both cold worked and annealed. Since there is no real necessity for spearheads to have very hard edges it is unsurprising that, in general, the spearheads had a much less severely worked edge than the swords examined, indicating that the extra working of the sword edges had been done deliberately to achieve a functionally optimal blade. The percentage of spearheads examined which are as cast or very little worked, although still small, does exceed that of the swords.

The shields of the period have been discussed in detail (Coles 1962) and, if those made of bronze were not lined with hide, a practice discounted by Coles (1962, 183), they must only have been of use for display and were probably only available to an 'elite'. It is not therefore surprising that the vast majority have been deposited in wet contexts. However, given the efficacy of hide and wood shields, it would be surprising if shields of organic material were not in regular use. A combatant armed with sword, spear and shield would have had to use the spear and abandon it in order to close in and use the sword, which, as attested by the existence of chapes throughout the period, was normally carried in a scabbard. Use of a spear and shield or sword and shield combination is much more likely, although the possibility of an unshielded sword and spear combination is feasible. There may well have been a custom that those with like weapons (and status) fought each other, as in the Middle Ages, but it is unlikely to have been rigidly enforced.

The relatively rare appearance of the bronze appurtenances of horse tack, within the weapon deposits, at least until the later part of the period, would indicate that horses were not a major factor in fighting. It is probable that a fighting force was made up of a mixture of unmounted combatants with a relatively small number (10-25) using swords, and a larger number (25-50) using spears or, possibly, axes. Most of these warriors probably used a shield of organic material. These numbers reflect the numbers of weapons found in some of the larger weapon hoards (e.g. Wilburton, Blackmoor and Waterden) which may, although it is far from proven, represent the armament of a single group. A unit designed simply to deter attack could well have been rather smaller, as the requirement would be merely to present a sufficient threat of inflicting substantial damage to ensure that any opportunist attacker would conclude that the potential gain was insufficient to merit the risk.

All of the participants in such forces would probably use the same suite of weapons, including swords, and these same weapons would also be used as personal arms by the individuals concerned, replacing largely the personal weapons in use prior to the adoption of swords. Hence the demise of the rapier, despite its efficacy in individual combat, would have become inevitable once the sword was widely adopted for group combat.

5.2 Weapon Deposition

It is highly probable that only a small percentage of the weapons of the period were actually deposited and that few of those which were deposited have survived, been recovered and conserved. However, the manner in which weapons were deposited and the differences in patterns of deposition over time are major sources of information as to how weapons and their role affected and were dealt with by society.

Some of the clues lie in the artefacts with which they were associated in deposition and some may come from the contexts in which they were deposited. Further pointers come from the way in which the weapons were treated prior to deposition and how these factors interrelate. The picture is very complex and a detailed investigation is required to tease out what patterns can be established before the attempt is made to integrate them into a deeper understanding of the place of weapons within society.

5.2.1 Weapon Deposition and Hoard Contents

Weapons, or parts of weapons, were present in a great many of the LBA hoards but those which featured a high proportion of weapons have been distinguished from other hoards of metal objects on several criteria. Foremost is the proportion of weaponry within the hoard. There is of course a problem with hoards which feature a large number of axes, which could be considered as either weapons or tools - the appearance of 'ingot' axes in Britain, akin to the poorly made continental Armorican Type (Briard 1976), is rare. The decision as to whether or not these constitute weapon hoards is largely a matter of judgement, based on the other contents of the hoard and the relative proportions thereof. Those hoards also containing 'prestige' items, such as cauldrons, flesh hooks and horse gear (Coombs 1975, 70 -74), would generally be accepted as weapon hoards, while hoards with a very few weapon pieces among a large number of axes and tools would not.

The subject of weapon hoard deposition during the Bronze Age was discussed in considerable depth by Coombs (1975). The contents of the weapon hoards are set out in detail (Coombs 1975, 54-68) and differentials are drawn between 'sword' and 'spearhead' hoards depending upon which weapon predominates. The 'spear' hoard is seen as possibly reflecting a standard armament of one or two spears with a shield while the 'sword' hoard is seen as a largely Northern and Scottish phenomenon, perhaps indicating a predilection for single combat (Coombs 1975, 74-75).

Certainly the tendency for the Scottish weapon hoards to be very small in terms of numbers of weapons and for these to be largely swords is marked, while the very large hoards, in which spearheads massively outnumber swords, appear disproportionately in East Anglia and the South East. Some more recent finds do tend to go against these trends. The St Andrew's hoard from Fife is a very large mixed tool, axe and spearhead hoard with only one piece of sword blade and a chape, containing numerous ornaments and pieces of horse gear (Cowie *et al.* 1991 and 1998). The Waterden hoard from Norfolk, has been expanded by recent finds into a very large accumulation of weapons with the number of swords represented not much lower than that of spearheads (Bridgford, in prep.). Nonetheless the overall pattern for hoards remains much the same.

Consideration of the non-hoard weapon finds of the period, especially from the River Thames, does go some way to mitigating this geographic difference in the pattern of proportions of swords and spears. The inclusion of these river deposits would help to redress the balance in the South by increasing the relative proportion of swords and this leads to some suspicion that the differences outlined above may reflect a pattern of differences in deposition practices and symbolic significance in addition to any differences in standard weaponry or fighting techniques.

5.2.2 Deposition Contexts

Weapons were deposited singly, cumulatively or within hoards in a wide variety of contexts during the period. However it is noticeable that a remarkably high proportion of weapons seem, from the reports within museum records, to have come from contexts which could reasonably be described as wet. Even given that some poetic licence may have been used in the descriptions of context for early finds, the predominant theme in East Anglia is of fens, while in the South East it is the River Thames which swamps other contexts. The weapons in major rivers, such as the Tay and the Tyne, and in Duddingston Loch continue this pattern in Scotland and North East England but elsewhere in the highland areas many of the small weapon hoards and individual weapon finds are described as 'buried in peat' or 'on clay below peat' and are found while digging drainage ditches. It is clear that even find locations which are now dry could well have been very wet places when the weapons were first deposited

It should be borne in mind that the numbers of spears and swords, examined in this study, are those for spears and pieces of spears and for swords and pieces of swords.

The data summarising context type according to region and typological grouping for swords and spears are tabulated in Tables 5.2.2 (i)-(iii) and illustrated in Figures 5.2.2 (i)-(iv). The proportions from wet and 'dry' contexts were tested for significant differences from population proportions using the Chi-squared distribution. All differences described as significant in what follows were shown to be statistically significant at the 5% significance level and the relevant Chi-squared statistics are shown in Appendix 1.

There was regional variation in the proportions of weapons from wet contexts, with East Anglia and the South East, at 46% and 49% respectively, being similar but in Scotland the proportion from wet contexts was only 32% while the Western proportion was 70%. The Scottish and Western proportions were significantly different from the population proportion of 46%, however the figures for total weapons disguise considerable regional variations in those for swords and spearheads when considered separately.

If all the weapons examined, representing over 25% of the existing total as estimated in Chapter 1.5 above, are considered, some 42% of swords and 48% of spears came from contexts which can confidently be defined as wet. The degree of fragmentation in spearheads from other contexts is less obviously different from that seen in the wet contexts than is the case for swords. Thus, although the initial proportion of spears and parts thereof from wet contexts by number exceeds that for swords and parts thereof, the proportion by 'complete weapons represented' would probably be substantially smaller.

There is regional variation in the proportion of swords coming from recognisably wet contexts, with East Anglia having the lowest at 29%, Scotland and the South East having 45% and 47% respectively and the much smaller Western total being split two thirds to one third in favour of wet contexts. These regional variations from the overall proportion of swords from wet contexts were statistically significant for East Anglia, the South East and the West. Many of the swords from other contexts are represented by only tiny fragments, while the majority from wet contexts represent a substantial proportion of the sword.

The subdivision of swords by typological grouping revealed substantial variation with the Early and Wilburton groups being overwhelmingly found in wet contexts while the deposition of Ewart Park swords was very biased towards contexts which were not recognisably wet.

Examination of the split between wet and 'dry' contexts for swords according to the edge damage rating revealed no statistically significant differences from the population ratio of

42:58. The swords with undamaged edges showed the greatest variation from this split, with only 33% being found in recognisably wet contexts, compared with 46% of those showing use damage and 43% of those which were deliberately damaged.

The overall figure for spearheads conceals a somewhat greater regional variation than for swords with only 21% of Scottish spears from wet contexts, while 49% of South Eastern, 60% of East Anglian and 71% of Western spears came from such contexts. The differences in the regional figures from those for the total were statistically significant for East Anglia, the West and Scotland. The East Anglian figure would be considerably lower, circa 50%, if the Waterden spearheads had been included. The strength of the deviation in Scotland may be misleading as a rather high proportion of Scottish spearheads have neither description of context nor does the reported location give any clue as to its 'wetness'.

The split of spearheads between contexts by typological grouping was assessed on the descriptive groups set out in Chapter 4.3 above and thus has rather less chronological significance than for swords although some groups, such as basal-looped, barbed and ogival, clearly belong only to certain parts of the time span considered. The only groups within which the split between wet and other contexts differed significantly from that of the population were the barbed, which favoured wet contexts, and the dumpy and ogival which generally came from other contexts.

All of the proportions calculated above may be subject to particular bias, especially those for the West which reflect the overwhelming importance of the Broadward hoard in the figures for that region (although other major Western hoards, such as Llynfawr (Savory 1980), which were not examined, also came from wet contexts). The proportions for weapons of the period within the British Museum collection, for example, are rather different from the overall figures in that only some 35% of swords and 13% of spearheads come from contexts which can confidently be described as wet, reflecting the importance of the River Thames swords, many of which are in the Museum of London collection, and the very large numbers of spears in the deposits of the East Anglian fens held in the Cambridge Museum of Archaeology and Anthropology. However, the figures do give an idea of the importance of wet contexts for weapon deposition. Furthermore many of the other contexts were not described in any detail and could easily have also been 'wet' at the time of deposition so that the calculated percentages probably understate the 'real' picture.

The dry land contexts range from those associated with settlement sites, such as the location of the Petters hoard in Surrey (Needham 1990) to remote areas, including some very mountainous regions, in the West and North. A few appear to have been found on mountainsides, overlooking passes, such as a sword from Cwmdu (grid ref: SO1726) in Powys or the early sword from Beddgelert (grid ref: SH6247) Gwynedd in an area close to the Sygun copper mine (Savory 1980, 113-4). Another sword, now in the collection at the City Museum, Stoke-on-Trent, is reported to have been broken into at least three pieces and the two recovered so far (K1.1982, K7.1996) to have been deposited on mountain tops two miles apart (Deborah Ford, Assistant Curator - pers. comm.). There are a number of fragmentary weapons in the environs of hillforts, both those of the period, such as the Breiddin in Powys (Musson 1991) and Beeston Castle in Cheshire (Ellis 1993), and those fortified later, such as Crowther's Camp Early Iron Age hillfort, 100m from which was found the large Guilsfield hoard of damaged weapons and tools (Savory 1980).

Consideration of the factors leading to the discovery of the weapons leads to the conclusion that those found to date may, in some areas, represent only a small proportion of those deposited. Discovery of the river finds has depended heavily on dredging operations, especially towards the edges of river channels. If river deposition at the level seen in the Thames was universal there may be large quantities of weapons in those rivers, all over the country, which have not experienced much dredging and there is a decided possibility that lake bottoms would merit further exploration.

Continued urban development in the highly populated lowland areas of South Eastern Britain where so many weapons have been found is likely to be accompanied by further finds. The fens of East Anglia, where so many finds have been made already, have largely now been drained, ploughed and, in recent years, metal detected. Nonetheless large accumulations of bronzes continue to appear both as a result of ploughing and of peat cutting and it is possible that more deeply buried weapons remain *in situ*.

Peat cutting and drainage in the highland areas of the North have yielded a number of individual weapons and smaller hoards to date and there is every reason to expect that this would continue were these practices to carry on apace. However, the development of forestry in many areas and recent moves to preserve what remains of peat bogs could mean that the numbers from such sources will diminish. Finds from mountainous areas have largely been accidental, except where nearby sites of archaeological interest, such as hillforts, are being explored or excavated and, although the level of weapon deposition in these areas does appear to have been low, there is probably more to be found.

The survival of some weapons, such as the spearhead with a medieval shaft (Needham *et al.* 1997, 86) from Lincolnshire, indicates that earlier finds may have served rather less academic purposes than those of the last two centuries. It is open to speculation how many deposits of the later Bronze Age have already been found and melted down.

5.2.3 State of Completeness of Deposited Weapons

The huge Isleham hoard has been interpreted (Northover - pers. comm.) as the 'scrap pit' of a major workshop due to the presence of a vast number of different artefacts, mainly broken up into very small pieces and including some which failed at various stages of manufacture, belonging to a wide range of typological groupings. Many of the pieces of this hoard, which, at around 90kgs by weight (Taylor 1993, 55), dwarfs any other from the period, certainly have the same appearance in terms of size and shape as the metal in the raw material bins in a modern foundry. This degree of 'breakage' is consistent with an intention to re-melt the metal and the necessity to reduce artefacts intended for recycling to small pieces would have been, if anything, more important in prehistoric times given both the limited size of crucibles and the difficulty in reaching adequate temperatures without very substantial effort in terms of bellows use. Although a number of other hoards, such as that from Minster, Thanet in Kent, shown in Plate 5.2.3(i), have contents, including weapons, similarly broken up, they are much smaller - the mean hoard weight for Southern Britain, excluding Isleham, in the Late Bronze Age was 2.75kgs (figures derived from Taylor 1993, 55, Table 9).

Other weapons, deposited singly and in hoards, had been broken before deposition but not necessarily reduced to such small pieces. Some of the breaks are very obviously not accidental combat damage - some examples are shown in Plate 5.2.3(ii)-(iv). As mentioned in Chapter 4.2.4 above these are extreme cases where the weapon had to be very substantially bent before it broke. Any substantial weakness in the metal would mean the break could occur without the need to apply so much force, making it more difficult to differentiate between deliberate and accidental breakage. The sword tip shown in Plate 5.2.3(v) probably did break accidentally due to internal porosity but the one in Plate 5.2.3(vi) was painstakingly 'decommissioned'. The damage to the two spearheads shown in Plate 5.2.3(vii)-(viii) indicates prior removal of the shaft.

It may also be difficult to differentiate between pre and post depositional damage if the latter happened a long time before weapons were found and conserved. It must be anticipated that some of the breaks were caused in relatively modern times, as a result of dredging, ploughing, peat cutting and quarrying - none of which employs delicate machinery. The first two in particular are likely to have thrown up and damaged or broken items which subsequently spent considerable time, as much as several centuries in some cases, within a 'fresh' environment and probably suffering considerable corrosion damage, which can hide even quite recent breaks. Most of what follows assumes that these cases form only a small minority of weapons examined, although some recognition of the potential for minor post depositional damage has been incorporated within the definitions used.

The weapons examined were rated on a scale according to how complete they were. Although there were differences in definitions for spearheads and swords they were broadly similar with the lowest rating (1) attributed to undamaged weapons and the second highest (8) to small fragments, similar to those described for the Isleham hoard. The highest category (9) was confined to weapons where there were two or more pieces of the same weapon present and this category could be further subdivided according to how much of the weapon these pieces represented. The ratings for swords are a much more reliable guide to the size of the pieces than those for spearheads, since the range of sword sizes is relatively narrow by comparison with that for spears. Some of the very small dumpy spears were so short that, even complete, they could qualify as scrap ready for re-melting. The definitions used are shown below:

Rating	Definitions
1	Swords: Complete and undamaged - 'entire' Spears: Complete and undamaged - 'entire'
2:	Swords: Complete but some damage - 'entire' Spears: Complete but some damage - 'entire'
3	Swords: Very nearly complete but extreme tip or terminal missing - 'entire' Spears: Complete in length but edges heavily damaged - 'almost complete'
4	Swords: Terminal plus most of tang or tip of blade missing - 'broken' Spears: Blade complete in length and part socket missing - 'almost complete'

5 Swords: Part blade and up to 3/4 hilt missing - 'broken'
Spears: Blade complete (possibly damaged) and socket missing - 'broken'

6 Swords: Over 3/4 blade or over 3/4 hilt present - 'broken'
Spears: Tip and part or all of socket missing - 'broken'

7 Swords: Between 100mm and 3/4 blade or 1/4 blade and 1/4 hilt present -'pieces'
Spears: Between 1/4 and 3/4 spear present - 'fragmentary'

8 Swords: Fragment (<100mm) - 'fragments'
Spears: Less than 1/4 spear present - 'fragmentary'

9 Swords: Two or more joining pieces present - 'multiple pieces'
Spears: Two or more joining pieces present - 'multiple pieces'

The proportions according to completeness categories were tested for significant differences from population proportions using the Chi-squared distribution with 5% significance level. All differences described as significant in what follows were shown to be statistically significant and the relevant Chi-squared statistics are shown in Appendix 1.

Figure 5.2.3 (i)-(ii) show the distribution by completeness category for swords and spears. Comparison of degrees of completeness shows that some 45% of spears and 26% of swords examined fell into the categories which could be defined as 'entire' (i.e. 1 and 2 for spears and 1, 2 and 3 for swords). The category covering weapons with more than one piece present comprised some 6% of spears and 13% of swords. These differences were statistically significant.

The completeness categories were grouped before further statistical analysis was undertaken. Groupings of the completeness categories for swords and spears differed in order to reflect as far as possible an intuitive division between weapons which had been treated differently before deposition.

The subdivision for swords had categories 1, 2 and 3 constituting the 'entire' swords, categories 4,5 and 6 constituting ' broken' swords, category 7 being sword 'pieces' and category 8 sword 'fragments', with category 9 being, as before, those with more than one piece present. The entire swords are most likely to have suffered only very minor damage, which was probably accidental and could easily have occurred after deposition. The 'broken' swords are those where a substantial portion of the sword is present but the break, usually at a vulnerable point, is likely to have happened either as a result of practical use or of deliberate breakage. The sword pieces represent minor parts of the sword, most of which would be considered too large for scrap and which are again likely to have been the result of either accidental damage during use or of deliberate breakage prior to deposition. The fragments, as mentioned above, are the pieces most likely to have been reduced for scrap but, of course, this category would include smaller pieces detached accidentally during use or deliberate pre-depositional breakage.

Category 9, where two or more pieces are present, contained 64 swords and gave rise to some additional problems in that a variable amount of the artefact is present. A further subdivision of this category into sub-categories 1 to 8 according to how much is represented shows that 36% of such swords are 'entire', 52% represent a relatively large proportion of the weapon and only 12% were pieces or fragments. Most do appear to have been broken before deposition but some may have been broken when first disturbed.

The variation in size for spearheads made such grouping of completeness categories rather more difficult. The 'entire' spearheads were deemed to be categories 1 and 2, with categories 3 and 4 constituting the 'almost complete' spearheads. categories 5 and 6 were deemed 'broken' spearheads and categories 7 and 8 were deemed 'fragmentary' spearheads. The entire spearheads certainly contain a number which were small enough to constitute 'scrap' even though they were essentially complete. The 'almost complete' spearheads represent a rather broad spectrum, ranging from entire spearheads damaged during deposition, through those broken as a result of pre-depositional activity, e.g. when shafts were deliberately broken, perhaps by wedging the spearhead, to those which were damaged during practical use. The 'broken' spearheads would include those corresponding both to broken swords and sword pieces, while the fragmentary spearheads covers a group corresponding both to sword pieces and to sword fragments, although most of the spearheads in this group are represented only by relatively small pieces.

Category 9, containing 29 spears, was further classified in the same manner as the swords and some 41% were entire with a further 25% almost complete, while only 17% were fragmentary. Although a few of the spearheads were obviously deliberately broken, a higher proportion of spearheads than of swords did appear to have breaks which look accidental.

Some 21% of spears and some 26% of swords, by number, were less than 100mm in length and could therefore be interpreted as scrap intended for re-melting, although such a direct interpretation is dangerous given the fact that the tips and hilts of swords and the tips and sockets of spearheads, which are usually small pieces, are also the most likely parts to be broken off accidentally.

5.2.3.1 State of Completeness of Swords

Comparison of the differences in state of completeness of swords between regions and typological groupings, as derived from the data summarised in Tables 5.2.3.1(i)-(v), also showed a number of statistically significant variations:

Figure 5.2.3.1(i) shows the regional distribution by completeness category for swords. The limited numbers of swords from the West mean that the results for this area are less than reliable but the lack of any broken swords or of broken swords with two or more pieces present was notable. The South East had a significantly higher number of fragments and significantly lower numbers of sword pieces and multiple piece swords than expected. The Scottish swords featured a significantly high proportion of 'entire' swords and a significantly low proportion of fragmented swords. The East Anglian figures showed significantly high numbers of multiple piece swords, significantly low numbers of entire swords and a significantly high percentage of sword pieces.

Figure 5.2.3.1(ii) shows the typological distribution by completeness category for swords. As in Chapter 4 above the very small number of Carp's Tongue type swords have been classified within the Late category despite the fact that they overlap with Ewart Park swords in South Eastern England and that there is some evidence from radiocarbon dating (Needham *et al.* 1997, 95) that they need not necessarily fall very late within the currency of Ewart Park types. The exclusion of swords whose typological group could not be ascertained cut the numbers in categories 7 and 8 dramatically and these two categories were therefore considered combined in all that follows.

The Early group showed a significantly high proportion of entire swords and significantly low proportions of broken and fragmented swords. Within the Wilburton group the proportion of broken swords was significantly high and that of fragmentary swords was significantly low. The Ewart Park swords showed a significantly low proportion of entire examples and a significantly high proportion of fragmentary swords. There were no significant deviations from the expected distribution within the small Late group.

Consideration of the variations between typological groups within each region was essentially restricted to East Anglia and the South East, since there were too few swords from the Western region for statistical analysis and the Scottish swords were so dominated by the Ewart Park group that comparisons were meaningless. The data are summarised in Table 5.2.3.1(iii)-(iv) and the results illustrated in Figures 5.2.3.1 (iii)-(iv).

Within East Anglia the proportion of Ewart Park sword pieces and fragments (categories 7 and 8) was significantly high, while the opposite was true of the Wilburton swords. In the South East the Early group had a significantly high number of entire swords and a significantly low proportion of pieces and fragments. The South Eastern Ewart Park swords had a significantly high proportion of pieces and fragments while the Wilburton group was significantly more concentrated in the broken swords (categories 4, 5 and 6).

There were significant regional differences within the Ewart Park sword group, the data for which are summarised in Table 5.2.3.1(v) and illustrated in Figure 5.2.3.1(v).

The East Anglian swords were significantly weighted towards broken pieces (categories 7 and 8) and to broken swords with multiple pieces present (category 9). There were therefore significantly few entire unbroken Ewart Park swords in East Anglia. This basically reflects the state of the swords in the large Waterden hoard which were generally broken into three or four pieces before deposition. In Scotland the Ewart Park swords had a significant tendency to be entire with a correspondingly significantly low proportion of sword pieces and fragments being present. Most completeness categories in the South East were in line with expectations but the number of swords with more than one piece present was significantly low.

5.2.3.2 State of Completeness of Spearheads

Comparison of the differences between regions and typological groupings, as derived from the data summarised in Tables 5.2.3.2 (i)-(vi), again showed a number of statistically significant variations:

Figure 5.2.3.2 (i) shows the regional distribution by completeness category for spearheads. A significantly high proportion of the South Eastern spears fell into the 'entire' categories (1 and 2). The spearheads from East Anglia differed significantly from expected proportions only in the 'almost complete' categories (3 and 4) where the numbers were significantly high. The Scottish spearheads were distributed much as would be expected from the total population statistics. The Western spearheads showed a low proportion in the 'entire' category but the number in the last category, which covered those broken but with multiple pieces present was significantly high.

Figure 5.2.3.2 (ii) shows the typological distribution by completeness category for spearheads. In this case it was decided to divide the spearheads by descriptive rather than 'chronological' typological groupings, given the large numbers of plain lanceolate spearheads without associations which could not be classified chronologically and the fact that similar considerations applied to some complex and dumpy types of spearhead found with swords of both Ewart Park and Wilburton types. Deviations from the expected proportions, as deduced from the population proportions, were found in most groups.

Among the basal-looped spears the proportion of fragmentary spears (categories 7 and 8) was significantly low. The barbed spearheads, although relatively few in number, did have a significantly low level of entire examples. The plain lanceolate group had significantly fewer entire and significantly more 'broken' (categories 5 and 6) spearheads than expected. The complex lanceolate group had a significantly low proportion of 'almost entire' spearheads and the dumpy lanceolate spearheads were significantly concentrated in the 'entire' categories. This latter would be expected given the small size and sturdy nature of the dumpy spearheads. The ogival spearheads also showed a significantly greater tendency to be 'entire', which is less likely to be a function of being by nature robust.

Investigation of the differences between typological groups within individual regions was somewhat restricted by the limited numbers in some completeness categories, especially in the Western region. There were no statistically significant differences between types of spears in the East Anglian region but in the South Eastern and, especially, the Scottish regions the proportions of entire plain lanceolate spearheads were significantly low and the proportions of complex lanceolate spearheads were significantly high, as shown in Figures 5.2.3.2(iii)-(iv).

When the regional distributions by completeness categories were examined for each typological group the significant differences again showed in the plain and complex lanceolate groups, as shown in Figures 5.2.3.2(v)-(vi). The Scottish group of plain lanceolate spearheads had a significantly lower proportion of entire examples than other regions. The proportion of South Eastern complex lanceolate spearheads in the 'entire' categories was significantly high and the proportion of entire Western complex lanceolate spearheads was significantly low.

5.2.4 Interaction between Deposition Context and Completeness of Weapons

Despite the fact that the contextual details for many weapons are inadequate and that some could therefore have been wet, there is adequate detail in sufficient cases to show some coherence in deviations from the 'wet' theme. In the South East and East Anglia, there are many weapon pieces within hoards of damaged or fragmentary axes and tools, a number of which also contain 'ingot material', deposited in apparently dry contexts. These include the Cambridgeshire hoards from Burwell Churchyard, Littlington, Milton Road and Green End Road, both in Chesterton and the hoard from Chrishall in Essex. However, a simple pattern of dry context, fragmented artefacts and metallurgical debris versus wet context, complete and prestigious artefacts in no way represents the complexity of the finds and their contexts. There are other hoards in the same areas, such as the Stuntney hoard in Cambridgeshire and the Cumberlow Green hoard in Essex, with very similar content, including 'ingot material', but which were very probably deposited in wet contexts; in the case of the former because it was found within a wooden 'bucket' in a peat bog and in the latter case since it was found during drainage operations (Catalogue of Bronze Age Collection of the Cambridge Museum of Archaeology and Anthropology, in prep.).

Several large hoards containing weapons, such as Petters (Needham 1990), Guilsfield (Savory 1980) and St Andrews (Cowie *et al.* 1991) are tight packed, indicating that they were buried in containers and, in the case of the latter, there are substantial remains of the textile wrappings. The first two contain items directly related to metalworking, such as casting debris, but the St Andrews hoard, which contains tools and a large number of ornaments, has no such debris. Again it would seem that a simple link, in this case between hoards in containers and metallurgical debris, fails to cover all circumstances.

To the extent that the data permit, the relationship between context and completeness was investigated for both spears and swords. In many cases the low numbers meant that significance could not be tested but, nonetheless some statistically significant differences did exist. The data were tested for significant differences using the Chi-squared distribution. All differences described as significant in what follows were shown to be statistically significant at the 5% significance level and the relevant Chi-squared statistics are shown in Appendix 1.

5.2.4.1 Swords - Completeness and Context

The data summarising connections between completeness and context for swords by region and typological group are summarised in Table 5.2.3.1(i)-(v). The categories of completeness were grouped as described in Chapter 5.2.3.1 above to facilitate analysis.

Firstly the swords from wet and 'dry' contexts were considered as separate populations. The data are illustrated in Figures 5.2.4.1(i)-(ii). There were several significant regional differences within both the wet and 'dry' groups, although the numbers in the West were too low for statistical analysis. In East Anglia there were significantly fewer complete and significantly more multiple piece swords than expected in the group from wet contexts. In Scottish wet contexts there were significantly fewer than expected entire swords and significantly more pieces than expected. The South Eastern wet contexts, primarily the River Thames, had significantly more complete and broken swords and significantly fewer sword pieces and fragments than expected.

The 'dry' contexts in East Anglia also showed a significantly low proportion of entire swords and a significantly high proportion of multiple piece swords, evidently a regional characteristic, but in this case the proportion of fragmentary swords was significantly low. The Scottish 'dry' context swords were significantly weighted towards entire and broken swords with significantly low proportions of sword pieces and fragments, which was in effect the reverse of the pattern for Scottish wet contexts. The South Eastern 'dry' contexts also largely reversed the wet context pattern with a significantly low proportion of entire swords and a significantly high proportion of fragments, while the proportion of multiple piece swords in the South Eastern 'dry' contexts was significantly low.

The differences in context type for each group of completeness categories within each region were assessed against the split between wet and 'dry' contexts for the region as a whole. The number of swords in the Western region was too small for statistical analysis to be valid but there were differences within other regions which proved significant. The data for these are illustrated in Figures 5.2.4.1(iii)-(v).

In East Anglia the 'entire' swords were significantly biased towards wet contexts and the same was true of broken swords while sword pieces were significantly more likely not to have come from recognisably wet contexts. A more marked version of this pattern was seen in the South East, with entire and broken swords significantly more likely to come from wet contexts although here it was sword fragments rather than sword pieces which were significantly less likely to come from wet contexts. This pattern was reversed in Scotland where both entire and broken swords were significantly less likely to be found in recognisably wet contexts while sword pieces and fragments were significantly more likely to have come from wet contexts. This pattern reversal may have been exaggerated due to the number of poorly provenanced Scottish weapons, as mentioned in Chapter 5.2.2 above, and was affected by the relative importance within the totals of the Duddingston Loch examples, almost all of which were damaged.

The differences in context type for each group of completeness categories within each typological group were assessed against the split between wet and 'dry' contexts for the group as a whole. There was little variation within either the Early or Wilburton groups, since both were heavily biased towards wet contexts in all categories represented. Within the relatively small Late group the entire swords were significantly more likely than others to come from wet contexts. The Ewart Park group, which was overall very biased towards 'non-wet' contexts, did have some statistically significant variations with the entire swords being significantly more likely than others to come from wet contexts, while sword pieces were significantly more likely to come from other contexts. This is illustrated in Figure 5.2.4.1(vi).

Within the Ewart Park swords, only those from the South East showed significant internal variation between completeness groupings and this was due to the significantly high proportion of entire swords from wet contexts and within the South East the Ewart Park swords were the only typological group to show significant deviation according to completeness grouping.

5.2.4.2 Spearheads - Completeness and Context

The data summarising connections between completeness and context for spearheads by region and typological group are summarised in Table 5.2.3.2 (i)-(vi). The categories of completeness were grouped as in Chapter 5.2.3.2 above to facilitate analysis.

The weapons from wet and 'dry' contexts were again considered as separate populations. There were fewer significant regional differences within each of these groups, than was the case for swords, despite the fact that the numbers of spearheads from the West were sufficient to permit statistical analysis. The data are illustrated in Figures 5.2.4.2(i)-(ii).

Most of the significant differences arose among the spearheads from wet contexts. In East Anglia there was a significantly high proportion of almost complete spearheads and significantly low proportions of fragmentary and multiple piece spearheads. In Scotland the proportions of entire and of 'broken' (categories 5 and 6) spearheads were significantly low while the proportion of fragmentary spearheads from wet contexts was significantly high. The wet contexts of the South East yielded significantly more entire spearheads and significantly fewer fragments than expected. In the West the wet contexts gave significantly high proportions of broken and fragmentary spearheads and a significantly lower proportion of entire spearheads than expected, reflecting the state of the spearheads from the important Broadward hoard.

Spearheads from the 'dry' contexts showed a rather more uniform pattern of completeness across the regions with the only significant differences from expected proportions being in Scotland, where the proportion of fragmentary spearheads was significantly low, and in the South East, where the proportion of fragments was significantly high and that of near complete spearheads was significantly low.

Analysis within each region of the split between wet and 'dry' contexts for each completeness category showed only a few statistically significant variations. There were none in East Anglia but in Scotland the differences were pronounced with the entire and the broken spearheads significantly weighted towards 'dry' contexts while the fragmented spearheads had a significantly higher than expected proportion coming from wet contexts. In the South East the fragmented spearheads were significantly weighted towards 'dry' contexts and in the West the same was true of the entire spearheads. The data are illustrated in Figures 5.2.4.2(iii)-(vi).

Analysis by typological group showed significant differences between the distributions by context type within each completeness category only within the two largest groupings, the plain and complex lanceolate spearheads, as shown in Figure 5.2.4.2(vii)-(viii). In the plain lanceolate group the entire spearheads were significantly weighted towards wet contexts while the broken and multiple piece spearheads were significantly weighted towards the 'dry' contexts. Among the complex lanceolate grouping the entire spearheads were significantly weighted towards the 'dry' contexts.

5.2.5 Deposition Patterns - Summary

The deposition patterns are undoubtedly complex and vary with both region and time.

The low numbers of swords in the West meant that, on a detailed level, there was no clear pattern apart from the tendency to favour wet deposition contexts which reflected the importance of the Broadward hoard. Western spearheads also were weighted towards the wet contexts and the majority were relatively incomplete. Indeed the more complete examples of all but the barbed spearheads tended to be found in dry contexts.

In Scotland any chronological variation in depositional practices for swords is largely obscured because the vast majority were of Ewart Park type. An indicator may be that the one Early and two Wilburton swords were pristine and deposited in wet contexts. A somewhat different picture was presented by the Ewart Park swords, of which the majority were entire but deposited in contexts which were not obviously wet. Scottish spearheads were even more slanted towards the 'non-wet' contexts, which were, as previously mentioned, not necessarily dry. This was true in all typological groups represented, with the exception of the sole barbed example examined. The basal-looped, complex and ogival spearheads all tended to be entire or nearly so while among both plain and complex lanceolate spearheads the majority of fragmentary spearheads came from wet contexts

In East Anglia swords tended to be incomplete but often a large part was present while a substantial proportion were broken with most of the pieces present. The swords which were complete or had a large part present tended to be found in wet contexts, although the seemingly dry context of the large Waterden hoard reversed the tendency for those with multiple pieces present to be found in wet contexts. This pattern of breakage was apparent throughout the period although there was a tendency for a higher proportion of Ewart Park swords to be present only as fragments than was the case for the preceding Wilburton swords. Spearheads in East Anglia tended more towards completeness than did the swords but, relative to other areas, it was again the high proportion of almost complete spearheads which stood out. The split between wet and 'dry' contexts was much more even than for swords and this applied to almost all completeness categories and types. The only notable variations were the preference for wet context deposition for near complete spearheads and for dry contexts for basal-looped, dumpy and more fragmentary spearheads.

Swords from the less common typological groupings were more numerous in the South East than in other regions and a better picture of change through time was thus available. Overall the South Eastern swords exhibited a tendency towards being fragmentary with fewer sword pieces or multiple piece swords than other regions but this partly obscured the chronological pattern. The Early South Eastern swords, as was the case with all regions, tended to be entire while the Wilburton swords, though incomplete, were substantial and the tendency to fragmentation was marked in the Ewart Park swords. Most South Eastern swords, except for the broken and, especially, the fragmented Ewart Park swords, were deposited in wet contexts. South Eastern spearheads, unlike the swords, tended to be deposited complete but, like the swords, the overall split between wet and dry contexts was fairly even. Again the more fragmented weapons tended to be found in 'dry' contexts. Basal-looped spearheads were almost all deposited in wet contexts while the later dumpy and ogival spearheads generally were deposited in other contexts.

The regional implications of these results will be further discussed in Chapter 6 below but the depositional practices must first be considered in conjunction with the social contexts of weaponry and warfare.

5.3 Social Contexts

There are many 'reasons' why societies, past and present, prepare for or engage in warfare; competition for resources, most often land, religious fanaticism and manipulation of minor grievances by cynical leaders are but a few among them. However, the archaeological evidence from the period does not support the existence of the large scale warfare likely to have been engendered by such circumstances. The evidence seen is more likely to have arisen from a tradition of group combat on a relatively small scale which was already in existence well before 1250BC, thus ensuring that the leaf shaped slashing sword, once introduced, was almost universally adopted. Any search for the motives for warfare and the societal adaptations to it must therefore be concentrated on those most likely to cause low level group conflict over a long period but which could increase in frequency with time, leading to growth, albeit sporadic, in the appearance of weaponry within the deposits of the subsequent five centuries.

Such a pattern would be exhibited by any form of conflict due to an increase in occasional contact with or competition between geographically separate groups of people, or by increasing pressure on economic resources or change in social structures engendering conflict, either between neighbouring groups, who had previously lived alongside each other relatively amicably, or within a previously coherent group. If the start of such conflict pre-dates the introduction of slashing swords then its causes must also do so.

This makes it a great deal less likely that the well documented climate deterioration of the Late Bronze Age and the inferred population 'slump', 'deduced' partly from a lack of axe deposits, (Burgess 1985), was an initial or sole cause - its onset being rather too late. Moreover, evidence of farming practices during the period indeed contradict the 'disaster scenario'; 'from about 1200-1400BC the field systems have started to reflect human geography and not natural topography alone. This is important because it shows that confidence was increasing and that farming communities possessed the practical knowledge to transcend many significant natural boundaries' (Pryor 1998, 144). Acceptance of Pryor's scenario of a prosperous lowland Britain utilising practices of increasingly intensive animal husbandry combined with 'kitchen garden' cereal cultivation from the Neolithic into the later Iron Age dictates the inference that climatic effects on resources were well controlled and only very localised conflicts would have arisen from or been exacerbated by them. It also implies the creation of surplus resources, at least in favoured lowland areas, which would have encouraged population growth and created the conditions in which non-subsistence activities, such as textile and ornament production, could thrive and grow.

Other activities which were increasing and for which there is ample evidence, include the use of metal, the long and short range exchange of artefacts and commodities, including metal, the use of horses, not necessarily as riding animals, and the deposition of material, generally 'valuable'. All of these activities stretch back at least into the Middle Bronze Age and, furthermore, all can themselves give rise to the motivation and the means to increase and expand them. Use of metal provides tools and 'wealth'. Tools increase the ability to produce other things, including boats and wagons, which make transport easier, and buildings to house people, animals and goods. 'Wealth' increases the ability to participate in yet more exchanges, thereby further accelerating the growth, while conferring the means to propitiate the powers of the unknown, honour one's ancestors and impress others. The motives are not purely economic nor are they entirely social; as with all such issues they are a complex and seldom totally conscious mixture thereof.

Whatever the motives, all such activities inevitably increase contact between people from differing backgrounds. Thus knowledge and ideas are exchanged and the mental connections are made from which all invention must spring. In some respects at least this scenario demands, if not an open society, at least one in which fresh ideas are not uniformly rejected. This implies that any intrinsic conservatism must be tempered by some level of individual autonomy or by the presence of an elite sufficiently self confident to accept the new, albeit possibly only rarely, and seek to derive advantage therefrom.

So, one may well ask, against this idyllic and 'progressive' backdrop, why all the weapons? There is indeed a reverse side to such a picture. The activities described above and their consequences are also potential causes of competition and conflict.

Increased wealth can lead to increased rivalry, resentment, theft and, ultimately violent conflict. Such problems are likely to be socially mediated within a coherent community in that individuals can be constrained, either morally or physically, by the accepted authorities and it would be difficult for any individual to overthrow the entire social fabric. However, where one community sanctions such actions against another the result can often be sustained mutual hostility erupting at times into bouts of armed conflict. The social sanctioning of such activities is incorporated into the communal ethos thereby eliminating the barriers to violence and, eventually, a new set of socially accepted 'rules' evolves which not only recognises the existence of the inter-communal hostility but positively reinforces it.

The emphasis on stock rearing inferred (Pryor 1998) from the field systems and, especially, the droveways in certain lowland areas, particularly the fens and the Thames valley, may well have led to a culture in which raiding stock was an 'acceptable' activity - a similar position to that seen on the Scottish borders in historic times, or set out in the Irish myths, as epitomised by 'Tain bo Cuailnge - the Cattle Raid of Cooley' (Bardon 1992). Conflict of this type would have been sporadic and have involved neighbouring communities but could continue over many generations.

Greater interpersonal contact across cultural and possibly linguistic borders presents greater opportunity to give and take offence, especially in those two most inflammatory areas of sex and religious belief. Where such offences simply involve individuals, it is generally the travellers themselves who must bear the consequences but, where the individual concerned can command either the ultimate loyalty of his community, or the immediate support of a group of trained and armed warriors, the outcome is much more likely to be inter-communal hostility involving not only the two original groups but also their allies. Where the communities are well separated geographically, such conflict is less likely to lead to a prolonged period of hostility and violence. While the involvement of others can escalate the conflict, especially if there is the prospect of gain in territory, wealth or prestige to be had, a resolution can often be more easily mediated through such allies.

More widespread travel involves undergoing the dangers of passage through unknown territory populated by those potentially hostile to such trespass. The transport of goods and animals over such alien territory may be a positive invitation to those inclined to have little respect for ownership 'rights' and a degree of armed protection may be deemed necessary for most travellers. The ability of a particular community to exercise control over the passage of people and property depends largely on the geographic location of the route and the availability of armed warriors to enforce compliance with any conditions required of those desiring passage. Such activities need not be entirely predatory; services, such as food, shelter, porterage and protection may be supplied in return for reward. However, the opportunity to derive benefit from the need of others to travel through community territory, especially where no viable alternative route exists, would be difficult to ignore.

In the face of such potential threats, and opportunities, it is entirely possible that, within each cohesive social group, the application of some part of community resources to the acquisition of weapons and the use of surplus time and energy, particularly on the part of younger, potentially disruptive males, in weapons training and protection duties, including those involving long distance travel, seemed appropriate. Furthermore it should be bome in mind that, for some at least, warfare is in itself a stimulating and rewarding pursuit, conferring benefits in terms of social position over and above more mundane considerations. Ultimately indeed the control of society may be transferred from the control of 'elders' to the hands of military 'heroes' even without any threat of violence. It was probably the prospect of just such an outcome which led to the custom of 'hiving' off of Samburu 'age sets' of young males to tend herds far away from the central territory thereby preserving the rights of the gerontocracy to dictate to the rest of society and to marry the young females (Spencer 1965).

There are of course a number of alternative explanations, some of which may, in part at least, be combined with the above scenario and others which contradict it. There remains a possibility that the increase seen in exchange of goods and contacts represents an entirely undesired imposition by groups less well endowed with worldly goods but well armed and prepared to use force to obtain what they wanted or by those persuaded that their beliefs and customs were superior and justified violent introduction to those less well equipped to resist. It is also feasible that an overthrow of long established social order led to continuing power struggles within social groups involving at least sporadic bouts of violent conflict or that the picture of prosperity presented by Pryor (1998) was disrupted by a half century of struggle to obtain the basics of subsistence.

Such explanations seem relatively unlikely, except perhaps as temporary phenomena, but the more extreme cases may just explain what happened to bring about one of the most obvious discrepancies between the Middle and Late Bronze Age; the abandonment of the death rituals which resulted in the ubiquitous Middle Bronze Age cemeteries of inurned burials of cremated remains. Perhaps, as Parker Pearson suggests, 'a certain proportion of the population were dumped in rivers' and/or 'most people at that time were cremated with their ashes scattered or buried in shallow pits without pots' (1993, 50) but this still constitutes a clear change in burial practices over a relatively short time period. Such changes in custom are unusual and would be expected to coincide with a change in social attitude towards death, ancestors, religious beliefs or all of the above. However it is difficult to reconcile this change with the seemingly much more gradual changes taking place in other spheres and the search for a comprehensive explanation remains tantalisingly beyond the scope of this study.

The social and religious concepts with which we must deal when considering warfare are among the most powerful known to humanity, second perhaps only to those of death and procreation. Physical violence between individuals is a relatively universal phenomenon, frequently seen but generally controlled within any functioning society. Organised warfare is an order of magnitude more compelling both in its fascination and its horror. As such it requires a very special treatment in terms of ritual and belief in order to control the effects on individuals of being involved with it and to insulate society from the dangers of the attitudes which it can engender. In effect the effort is made to 'ring-fence' with ritual the dangerous nature of organised violence and to inculcate in participants the concepts of social cohesion and duty to a higher power, whether human or deity. While weapons undoubtedly function as symbols of rank and status for individuals they are symbolic of issues a lot more vital, powerful and frightening to others.

Many authors have noted the 'Celtic' predisposition to make offerings at watery places (Coombs 1975, 70) and most have connected deposits in watery places during the Bronze Age to ritual practices (Coombs 1975, Colquhoun & Burgess 1988, Levy 1982, Bradley 1990, Pryor 1992). There seems little reason to argue against the application of such theories to weapons, particularly swords. Indeed Pryor, during the course of his long running excavations at Flag Fen, has moved from suggesting that many fenland deposition sites may have been dry and that riverine deposition could well be the result of erosion of settlement material (1980, 489-90) to an appreciation of the liminal nature of certain sites and the complexity of the ritual processes which have taken place there (1992, 528-9).

Although weapons were not the only items of value deposited in wet contexts they do seem predominant in the later Bronze Age. To assume that all were deposited for identical purposes stretches credulity but to identify particular deposits with specific motives is far from simple. Inferences have been made in certain cases; the Flag Fen deposits are currently interpreted as 'offerings to the ancestors...made perhaps when someone died or during commemoration of an important family anniversary' but 'they speak of a society where an individual's power and prestige are now of enormous importance' (Pryor 1998, 135).

The fact that weapons at Flag Fen were deposited at such a site over several centuries, individually and apparently carefully placed, when taken together with the unique nature of the 'child scale' sword, less than a foot long, deposited there, certainly supports some link between the deposited weapons and individuals. The site, illustrated as 'reconstructed' in Plate 5.3(i) with the miniature sword inset, provided an atmosphere highly appropriate for negotiating the boundary of the supernatural sphere on behalf of the dead, possibly in a rather subdued and sombre ceremony. Symbolic 'killing' of the weapons before deposition is indeed consistent with the type of damage seen in some of the weapons. However, a personal deposit on the part of the living, symbolising perhaps some regret over past actions or thanks for a narrow escape, would equally fit the evidence.

Bradley (1990, 107-9) equates at least some of the Late Bronze Age weapons of the River Thames directly with funerary practices, citing skulls of adult males from the same context, which were radiocarbon dated to the same period, as circumstantial evidence. Again there are explanations, other than the purely funerary, for the existence of conglomerations of ritually deposited weaponry, both complete and broken, in certain reaches of major rivers but there seems little reason to discount the likelihood that some of the weapons deposited were accompanied by human remains, perhaps of those who died in battle, whether or not the person concerned had once owned the weapon.

There is likely to be some symbolic significance in the difference between deliberately broken and complete swords. Aside from the rather mundane consideration that a broken weapon is not available for re-use there may simply be a straightforward connection between say the 'death' of the sword and the death of the rightful owner. It could be that only those of a particular rank were permitted to sacrifice complete weapons or that only complete weapons were acceptable as propitiatory offerings. There are indications, as demonstrated in Chapter 5.2.4, above that the symbolism invoked may have changed over time, with the earlier practice favouring complete weapons. and varied regionally but this gets us no further towards comprehension of what the symbols meant to those who understood and manipulated them.

There are some very obviously broken and burnt conglomerations of weapons which, from the similarity in typology and condition, appear to have been deposited simultaneously in wet contexts, notably the Wilburton hoard from the fens and the weapons and cauldron parts from Duddingston Loch in Edinburgh, some of which are shown in Plate 5.3(ii).

'The Wilburton hoard was found on clay under a heavy peat layer in a field which was, according to local hearsay, set alight in order to 'improve' agricultural potential and the state of the hoard has therefore been attributed to the effects of the peat burning (Evans 1884). However, when the microstructure was examined, corrosion near the edge followed the boundaries of the large grains indicating that these large grains were present before the corrosion penetrated. Corrosion normally stabilises soon after deposition (Robbiola *et al.* 1992) and corrosion around small grains would remain to inhibit the growth of large grains during any subsequent recrystallisation. The microstructural evidence therefore tends to contradict Evans' theory and suggests that the burning took place before deposition.

The microstructure of all the Duddingston samples also shows the symptoms of burning and, since it is highly unlikely that the waters of Duddingston Loch have ever been set alight, the weapons there must have been burnt before deposition. The records of the finding of the Duddingston bronzes include a report that bones (possibly human and subsequently lost) were found with them.' (Bridgford 1998, 210-12)

There were other obviously burnt and fused weapons, as shown in Plate 5.3(iii) deposited in the Thames, though the quantities are less impressive and, as mentioned in Chapter 2.3 above, there are other less obvious examples whose microstructures indicate that they were probably burnt. None of these has the appearance of a 'scrapped' weapon since the pieces are too large for crucible melting, and their wet contexts mitigate against any such interpretation.

It is certainly tempting to see the deposition of these weapons as the final act of a cremation ritual or as the culmination of the ritual destruction of the weapons owned by those whose cremated or excarnated remains were, in some cases at least, deposited with them. Some attention must be paid to the sheer numbers of weapons included in the first two hoards. These depositions represent weapon destruction on a large scale and the 'Celtic victory rituals' described by Caesar (Coombs 1975, 70) certainly do seem relevant. Such rituals would surely be rare but would serve to thank and propitiate the deities, display the extent of a victory and the lavish 'waste' of captured valuables and underline the total humiliation of the enemy. They could perhaps mark the death of a major leader with the extent of the destruction intended both to honour the dead and increase the prestige or legitimate the position of the successor. In either case such displays would surely only take place where they would be ritually valid, hence the use of sacred places, but where they could also be seen by the desired audience. This would be a major ceremony, not a simple disposal of battle dead.

The small weapon 'hoards' and single swords found in peat and mountain sides in highland areas of the North and West speak of a very different type of ceremony on a much more individual scale. Again the death of a warrior or the dedication of an individual's weapons to the gods in a bleak and isolated sacred place, perhaps on the edge of a territory, seem appropriate circumstances. The swords thus deposited again seem to vary as to state of completeness with some almost pristine but others deliberately broken and often incomplete.

No real preference for the deposition of swords with no sign of edge damage in the more obviously ritual contexts was found, except perhaps among the earliest weapons. If only pristine swords could serve as gifts to the gods or the ancestors, or were suitable for use in an afterlife, then they shared their contexts with weapons which had been used in battle and were deposited ceremonially for less elevated purposes

Traditional 'economic' interpretations, of 'personal', 'merchant's' and 'founder's' deposits, as initially used by Evans (1881), are often invoked to 'explain' deposition, especially in dry contexts. Undoubtedly people do occasionally need to hide their possessions, whether they own them by way of 'trade' or otherwise but, while there may well be practical reasons for the 'loss' of deposited bronze artefacts which were originally put in place for utilitarian purposes, it is difficult to accept the frequency with which circumstances must therefore have conspired against their subsequent retrieval.

The Gilmonby hoard, which was discovered during drainage work close to an old water course in what may therefore have originally been a wet context, has been interpreted as a scrap hoard (Coggins 1983) but contains a large number of spearheads, most of which are damaged, pieces of at least four Ewart Park swords, a bizarre collection of very different socketed axes, cauldron pieces, copper ingots, specialised tools and many fragments of bronze. This may be a case where axes could count as weapons which would lend it most of the features of a ritually deposited weapon hoard - perhaps of captured weapons and other booty.

It need not necessarily be the case that the presence of broken artefacts, metallurgical debris and copper 'ingots', imply that a deposit was not made for ritual purposes. Consideration has to be given to an alternative understanding of 'value' which may not understand an ingot as a simple commodity or a broken artefact, in a context where it is clearly not destined for practical use, as less valuable than an entire one. We do indeed appreciate the concept that an artefact's history can be its most valuable attribute - many parts of the modern 'heritage industry' rely on the concept. It is not an enormous step to appreciate that any product of such 'magical' and 'powerful' processes as smelting, refining and casting may be imbued with some of the mystery of its formation. Indeed however scientific one's understanding or clinically economic one's analytical viewpoint the pouring of molten metal remains to this day an awesome sight.

Deposition of broken weapons in 'dry' contexts does show substantial variation. The highly fragmented items in mixed hoards seem unlikely to have been deposited for the same reasons as the broken weapons in hoards of weapons or of weapons and axes and their presence is less likely to be symbolically connected with warfare or warriors. Notwithstanding the fact that some 'dry' contexts may originally have been wet, substantial weapon hoards may also come from dry land. The very large Waterden hoard from Norfolk, although ploughed out from its original context, does seem to have had a dry burial yet it has many of the features seen in the Wilburton hoard, including deliberately breakage of swords and even some burnt weapons. Despite comprehensive metal detection sufficient of the swords were incomplete to indicate that the weapons were broken elsewhere. They were evidently buried just below the crest of a SSW facing slope (Andrew Rogerson - pers. comm.), probably in close proximity, possibly even in a container, though no sign thereof now remains. Perhaps in this case it was the visibility of the proceedings which took precedence but it is difficult to envisage the deposition as other than ceremonial.

The variety seen in the acts of weapon deposition is considerable but some examination of contextual detail more often than not leads to interpretations which are ceremonial, symbolic and spiritual. Even if many such acts are concerned with particular death or victory rites they are simultaneously, by the mere presence of weaponry, inextricably bound up with the concepts of warfare. The complexity and frequency of the use of weapons as symbols in ritual amply demonstrates how central warfare was to the cultural and religious life of people. This does not demand that it was central to daily life, indeed for the bulk of the population the opposite may well have been true, but it was a very powerful force in both fact and imagery - a source no doubt of fear and dread but also of songs and tales which lost nothing in the telling.

6 Regionality

The existence of regional differences within Britain is universally acknowledged even in modern times. These differences depend on geography, economic factors and cultural variation and this last still remains important despite the presence of universal education, nationwide institutions and mass media. The existence of such differences between groups of people living within the then very different and probably much more self contained regions during prehistoric times should therefore come as no surprise. Indeed it is the extent of the discernable similarities displayed by the material culture remaining which could be viewed as surprising.

British society in the later Iron Age is known, both from the Roman literature and the archaeological record, to have been organised into 'tribal' groupings possessing a relatively sophisticated, if hierarchical, system of government, with widely accepted mechanisms to enable leadership to pass from one generation to the next. They were well armed and well prepared for combat and had constructed a network of impressively defended hillforts. These 'tribes' controlled distinct regional territories but had interlinking alliances, including those with 'tribes' overseas, and widespread trading patterns, which included a degree of regional specialisation (Darvill 1987, 162-184). This type of society does appear to have evolved rather than been imposed and its roots must therefore lie in the Bronze Age. An investigation of the extent and significance of regional differences in the design, manufacture, use and deposition of the weapons of the Late Bronze Age shown up by the analyses undertaken herein, should provide further understanding of the territorial nature of society in that period.

In what follows comparisons of evidence which impinges upon the production, use and deposition of the weapons examined and the cultural contexts in which they were set. are made between four regions: Scotland and North East England ('Scotland'), East Anglia and the East Midlands (East Anglia), South East England (South East) and South West England, Wales and the Marches, the West Midlands and North West England (West). These were defined in Chapter 1.1.4 above and illustrated in Figure 1.1.4.

6.1 Raw Materials - Metal Production and Circulation

Clearly, given the relatively sparse distribution of copper and tin sources, there is bound to be some evidence of regionality in the production and circulation of metal. Although there is an increasing amount of evidence for mining sites, as set out in Chapter 1.3.4, the difficulties in tracing metal 'sources', discussed in Chapter 1.5 above, and the prevalence of recycling in the Late Bronze Age mean that the bulk of the evidence for regionality in the use of metal comes from regional differentiation in the chemical composition of the artefacts and not from tracing directly the path from mine to artefact.

As discussed in Chapter 1.3.4 above there is clear radiocarbon dating evidence that, at least among Welsh early copper mining sites, there was activity during the period here considered. The dates which have been determined are illustrated in Figure 6.1(i) and the two sites are illustrated in Plates 6.1(i)-(ii). The continued lack of identifiable sites in Scotland and the South West may possibly be due to the absence of diagnostic hammerstones in these areas, indicating perhaps different mining procedures (Craddock 1995), although recent surveying activity in Scotland is beginning to yield some such finds (Timberlake - pers. comm.). A map showing the location of a number of early sites is given in Figure 6.1(ii).

Some artefacts from the Early Bronze Age show trace element and lead isotope profiles consistent with Welsh or Irish copper sources (Rohl 1995, 170-1). It seems reasonable to assume that some of the copper in circulation between 1250 and 750BC was also smelted from ores mined in these and other highland areas, although the presence of added lead in the alloy, common throughout the period under consideration, prevents lead isotope analyses from adding corroborating evidence.

The results of the trace element analyses, discussed in Chapter 2.6 above, only provide hints that there may be some use of metal smelted from local ores. The variations in distribution among the different compositional groups, particularly in the concentration of the Western and Scottish samples from the dominant Ewart Park grouping, within certain of the compositional groups, may indicate the addition of metal from within these regions to metal from external sources, whether as freshly smelted metal or 'recycled scrap'.

The lack of nickel in Early Bronze Age Scottish artefacts (Cowie *et al.* 1998, 152) appears to have been carried through to the Late Bronze Age in the guise of the concentration of Scottish weapons in the compositional groups (6, 7 & 8 - defined in Chapter 2.6.1.1) exhibiting low nickel levels and low nickel to silver ratios. The concentration of Western weapons in the group (9) with little or no silver content is consistent with the presence in Western Early Bronze Age artefacts of metal from Northover's Early and Middle Bronze Age compositional groups B (principal impurities arsenic and nickel), C (very pure - no principal trace elements), G (principal impurity nickel) and, especially, E (principal impurities arsenic, antimony and nickel) (Northover

1980, 230-232). Northover's EBA Group E is common within the Arreton metalwork phase of Southern Britain, which occurs in Needham's Period 4 (1700-1500BC). Those South Eastern Late Bronze Age weapons having little or no silver content tend to come from the Western edge of that region, adjacent to the Isle of Wight where the Arreton hoard was found. The ultimate source giving rise to Northover's EBA group E is, given the presence of nickel and antimony, more likely to belong in continental Europe (Northover - pers. comm.) than in Britain and may therefore indicate the re-opening of an exchange route rather than use of local copper.

The apparent reduction in overall trace elements over time seen in the difference between Wilburton and Ewart Park weapons, discussed in Chapter 2.6.1.1, is likely to have resulted at least in part from the addition of relatively pure copper to the original Wilburton metal, with its rather high trace element levels. Again the availability of very pure copper from Western sources is indicated by the Early Bronze Age artefact analyses (Northover 1980, 230-232). Mixing with copper or bronze, recycled or otherwise, with lower levels of trace elements, would dilute the characteristically high trace element levels of the Wilburton assemblages. Recycling itself could also have contributed to this process over time. In particular the two Late Bronze Age groups identified in Chapter 2.6.1.2 which exhibit relatively low arsenic levels (5 & 8) are likely to reflect a tendency to lose relatively greater amounts of volatile arsenic during recycling. However, it is likely that the lowering of the trace element levels over time was due to a combination of all these processes.

The fact that differences in trace element patterns are less than clear cut owes much to the mixing of metal from a variety of sources to produce the weapons analysed. The changes over time are confounded with those due to exchange patterns and exploitation of local resources in such a manner that only substantial numbers of analyses can pick out any consistent patterns of behaviour in the production and use of copper.

The use of metal from non-native sources appears to have been widespread in Britain for most of the Bronze Age (Northover 1982a). Thus the emergence of the high impurity groups with nickel, silver arsenic and antimony as the major trace elements, which Northover identifies as having an Alpine or Central European source area, with the Early swords from the South East seems to form one part of a pattern of exchange which encompasses the British Isles and continental Europe. Bronze with this type of impurity pattern dominates the highly regional, lowland, Wilburton type metal work and the effects of its recycling are probably a major factor in the impurity patterns of later artefacts from the lowland areas.

The association of the first appearance of this metal composition with what is, for Britain, an innovative weapon type, the first examples of which are widely presumed to have been of Continental manufacture, may well be indicative of the means by which this particular exchange was initiated. This is not to say that the exchange was enforced at sword point but that the exchange of unusual or high status items is frequently the first material sign of new contacts between culturally separate groups of people. Unfortunately it is also the case that those venturing among unfamiliar people will generally carry weapons with them lest their welcome be less than overwhelming. The fact that the first examples were deposited in the Thames in a manner quite consistent with that used for indigenous Middle Bronze Age weapons indicates that the swords in question, whether exchanged willingly or captured violently, had most probably ended up in the hands of the people of that area and that they were, therefore, treated symbolically in the manner traditionally used locally for the most impressive weapons. The expansion in use of the metal from which they were made into the clearly indigenously made Wilburton metalwork does tend to indicate that a relationship of relatively long duration was established.

The reciprocal side of the exchange, assuming that the process did actually constitute exchange, is unknown but Pryor's work (Pryor 1998) points to the existence of very large sheep and cattle herds in East Anglia and the South East, providing ample scope for surplus sufficient to enable some of the population to produce secondary products, such as fine textiles, which could be exchanged for metal or other items which were not available locally. It may even be that small numbers of highly prized animals were themselves the subject of exchange; Pryor has pointed out the requirement for the regular introduction of fresh genes into the breeding stock and the satisfaction of this need, despite problems in transport, may have applied to cross-Channel as well as internal contacts. The coincidental satisfaction of similar need within the human population has also been noted (Pryor 1998).

There remains the much touted possibility that tin was 'exported', from the South West, via the Thames and across the Channel. A few considerations mitigate against this suggestion; firstly the tradition of direct contacts, via sea, between the South West and the continental Europe, secondly, the fact that, although tin is relatively rare, there were tin sources available in Brittany and in Central Europe. In addition there is ample evidence for the transportation of bronze, as both complete and broken artefacts, in the form of 'shipwreck cargoes', such as Langdon Bay off Dover and Moorsands off

Salcombe in Devon (Darvill 1987, 121), but none for the transport of tin as a separate commodity, although this in no way proves that such transportation did not take place.

Similarly there is very little evidence for the long distance transportation of unalloyed copper in Britain although some sites, such as Petters Sportsfield (Needham 1990a) and Gilmonby (Coggins 1983) among others, have produced relatively small lumps of unalloyed copper, among an assemblage of bronze objects, which could be interpreted as the residue of copper 'ingots'. It is unlikely, given transportation problems, that copper was smelted at any great distance from where it was mined and it is feasible that unalloyed copper then entered the system to be mixed with recycled bronze or alloyed with tin at a later stage.

The bulk of the 'shipwreck cargoes' appear to have been made up of finished artefacts, many of which were broken. A number were of clearly 'foreign' type but the very rarity of such obviously foreign made artefacts in Britain would indicate that such cargoes were intended for re-casting rather than for direct use. Some cargoes may even have been in transit from one 'port' in Britain to another, due to greater ease of travel by boat, rather than having been the result of overseas transport. Overall there is little to indicate the direct import of finished goods from the continent for use in Britain, other than as a source of bronze, although a few swords deposited in Britain, especially among the Early types, may have been manufactured on the continent. The vast majority of weapons and tools found in Britain differ sufficiently from continental examples in their detailed typology to conclude that they were made in Britain and not imported. However, the similarities which do exist, especially in weapon design, clearly indicate that items from elsewhere were not totally unfamiliar to some at least among the indigenous metal workers or 'commissioners' of the artefacts.

It must be underlined that the existence of some very long distance exchange contacts both within the British Isles and between them and Continental Europe are known to have existed from at least as early as the Neolithic period, in particular the ability to identify source areas for particular types of stone and flint from which highly prestigious artefacts, such as the Langdale stone axes, were made has shown how far unique materials could travel. The major differences between such 'exotic' materials and bronze are the underlying utility of the latter, which not only permits the manufacture of the tools by which the means of transporting exchange goods in ever increasing quantity may be produced but possesses the unique property that anything made from it may be transformed into another desired object by means of melting and re-casting.

6.2 Weapon Production - Workshops and Weapon Makers

Another area where evidence for regional differences requires investigation is that concerning the production of the artefacts, and particularly, in this case, the weapons. The evidence can be divided into that provided by excavated sites on which evidence for metal working activities has been found and that provided, via microstructural analysis and visual inspection, by the artefacts themselves.

6.2.1 Metal Working Sites

Ideally, given sufficiently widespread investigation, it should be possible to map the distribution of of sites where metal working took place. These would either have been excavated or surveyed and recognised as such and would have produced artefactual evidence which could then be compared. While such widespread investigation of potential mining sites is underway, the recognition of metal working sites has generally been due to chance. Indeed, it is entirely possible that, in many early excavations, the evidence for such activities was not even recognised or recorded. Thus the number of sites identified is small and the production of any representative regional breakdown is not currently feasible. However, despite the fact that there is not much direct evidence left of the physical contexts in which weapons were made during the Late Bronze Age, that which there is does give some interesting clues about the makers. This evidence, a substantial part of which is not yet published, is discussed here.

The clay moulds for LBA swords, complex spearheads and some axes, in particular, show an interesting distribution. Although, by contrast with the weapons made in them, many are found within so-called 'forts' a number come from sites which were initially interpreted as settlement sites and from sites still thought of as enclosed 'farmsteads'. On closer examination of the evidence there are enough anomalies to make one suspicious about any strictly economic or domestic interpretation of these sites.

The site of Thwing in the Yorkshire wolds was described in the mid 1980's as a 'settlement' lying 'within a defended circular enclosure' with 'in the centre of the site a large circular house' from which 'came many objects of a domestic character ' 'including a quern, two rubbing stones, 2 complete loomweights, spindle whorls pottery and animal bones of cattle pig sheep and horse'. The presence of bronze weapons and personal ornaments is also mentioned (Darvill 1987, 115).

By early 1992 the excavator had reinterpreted the site as one with 'not entirely functional monumental architecture', probably ritual in nature, which had over time developed into a massive and fortified site. The great central building hid a complex of earlier structures including a central hollow dug into chalk with a flat topped chalk plinth. In the next phase pits and a ring of post holes were dug in and a burial pit was inserted in the trampled floor. This was followed by another ring of posts further out and another pit containing an urn burial and covered with chalk slabs (a very rare feature in the Late Bronze Age).

Areas preserved by the later rampart included a hearth to the West and bronze working crucibles and mould fragments from spear and axe moulds. and, in addition, the site contained a trough shaped feature of the type usually interpreted as an oven or boiling pit for cooking large quantities of meat and therefore associated with feasting. (Manby 1992 - unpublished paper given to The Society of Antiquaries).

Another site with similarly ambiguous features together with a substantial deposit of metal working debris, including a high proportion of weapon moulds, is Rathgall, Co. Wicklow, excavated by Raftery in the late 1960's and early 1970's. Again the site has a large central building with a plinth, below which was found a gold ornament. Cobbled areas and hearths, interpreted as metal working areas, are plentiful there and cooking troughs also appear (Raftery 1971).

The Breiddin hillfort in Powys has 'a complex of pits, furnaces and working hollows' (Musson 1991, 57-61) radiocarbon dated to 710+/-80bc(HAR -1223) from twig charcoal. There were fragments of clay mould and crucibles (Tylecote and Biek 1991, 147-9) and an assemblage of bronze objects including a few weapon fragments and many ornaments typical of the Late Bronze Age (Coombs 1991, 132-9).

Springfield Lyons in Essex was also initially interpreted and reconstructed as an enclosed farmstead (Darvill 1987, 114-5). However, if the presence of a large central circular building, large quantities of broken 'fineware', numerous causeways and a monumental East entrance (Buckley and Hedges 1987) were not sufficient to arouse suspicion that this was not an entirely domestic site, the two large deposits of broken clay moulds for Ewart Park swords buried in the ditch terminals of the two opposed main entrances should (Needham 1987). There was no other metal working debris within the site and the relative juxtaposition of the mould pieces indicates that they were deposited en masse. Such a deposition may not only mark the foundation of the 'ring fort' burt also the 'foundation' perhaps of a 'warrior order' which gathered within the enclosure and for which new swords were a prerequisite.

A similar, though smaller, deposit of mould fragments in a pit, also possibly an entrance terminal, at Norton Fitzwarren hillfort relates to the Late Bronze Age 'Ewart Park' metal working phase, although the actual bronzes, ornaments and axes found at this site, relate to the Middle Bronze Age 'ornament horizon' (Needham 1989).

The fact that those sites, in which clay moulds have been found, which have been examined in detail most recently are almost all showing signs of uses other than domestic or military does lead one to suspect that other accepted settlement or fortified 'settlement' sites with metal working remains, such as Traprain Law in Lothian and Jarlshof in Shetland may show similar characteristics.

While weapon production at the so-called fort sites might be attributed merely to a military context such an interpretation is probably too simplistic. Close examination of the evidence points to a rather more complex interrelationship between the manufacture of weapons, warrior groups and ritual structures in society.

Less easily explained are metal working sites, with mould fragments, found remote from any obvious contemporary context. One site near Tewkesbury, lies in what is still the floodplain of the River Avon. There were several amorphous pits, some containing burnt material, mainly stones and charcoal flecked red earth, showing in the glutinous mud. One large spearhead mould, probably used to produce a basal-looped triangular bladed spearhead (Needham, in prep.) had been found buried in another small pit nearby. Evidently during flooding the areas containing the pits would have been islands cut off from the surrounding countryside and, as such, naturally bounded. Another site near to Tewkesbury, Sandy Lane, has produced a mould piece from a fillet-defined spearhead, circa 1000BC, found near to a burnt mound on the bank of a water course (Bridgford, in prep.).

The well documented site at Dainton in Devon yielded a similarly militaristic assemblage of clay moulds. The site was set in a Late Bronze Age field system with limestone revetted field walls and tenuously linked to a spread of, possibly occupation related, pottery debris and some cairns which were once interpreted as hut sites but, when excavated, seemed likely to be clearance cairns, one of which contained some human skeletal material (Needham 1980).

The impression given by these manufacturing remains is that the process of producing Late Bronze Age weapons, and possibly other bronze items, may in some cases have been rather secretive. The contextual detail from some of the sites seems to point towards complex ritual associations and the exclusion of the uninitiated. The early myths and medieval historical evidence from Europe point to a similar need to circumscribe the 'magical' transformations of ore to metal and metal to artefact, held by public and metalworker alike - a continuity of belief and practical application lost in the modem era. It is unlikely to be co-incidental that prehistoric production often took place and evidence was deposited (or even hidden) in sites either totally cut off from general use or associated with various facets of ritual (or both) and it seems highly improbable that the production process itself was not irretrievably interlinked with religious beliefs and practices.

The fact that the vast majority of the identifiable mould pieces from these sites are related to weapon manufacture may not indicate that they were exclusively dedicated to the manufacture of weapons. Swords and long spearheads are probably best made in clay moulds but other artefacts can easily be made in moulds which leave no trace, such as sand, or which are re-usable and easily transported, such as stone or even bronze. A stone mould for Stogursey type LBA axes was found in the same area as the Petters metalwork hoard, although the area concerned, by Runnymede on the Thames, lies outside the main concentration of deposition of Stogursey axes, in the South West and Wessex (Needham 1990, 75)

The sites which have been investigated are too few in number to establish any sort of pattern. The evidence of metal working within hilltop enclosures is obviously confined to upland areas but in certain respects, such as the working areas and the bronze metal work assemblages found they may resemble the areas within major lowland sites such as the Runnymede area, once thought of primarily as a river island port but recently re-interpreted by the excavator as a 'nodal' site where large numbers of people gathered at intervals to participate in communal activities such as feasting, with manufacturing of all types linked to such episodes (Needham - pers. comm.). The connections between ringforts in the South East and weapon manufacture may owe rather more to their association with the end product than to their use as metal working sites. The evidence of metal working within the floodplain at Tewkesbury is indeed Western but it remains possible that alluvial deposits elsewhere in lowland areas could hide similar sites and it is highly likely that sites similar to the open one at Dainton exist elsewhere. The site evidence from the East is sparse. There were substantial numbers of fragments of clay moulds for basal-looped spearheads, found in a midden within a shaft at the much used area of Grimes Graves in Norfolk (Needham 1991) and, if the Isleham hoard is, as it appears, a remnant of a workshop, projected further excavations in the area might yield some details of yet another site, where the scale of manufacturing may well have exceeded that in any of the other sites investigated to date.

6.2.2 Manufacturing Techniques and Practitioners

The experimental work described in Chapter 3 and that undertaken by O'Faolain (1997) has shown that the production process had to be a team effort which required very specific knowledge and skill and immense perseverance. The sword makers were often working at the extremes of toleration of their material and any slips were likely to lead to total failure, requiring the entire lengthy procedure to be started again from scratch. The skills and knowledge required to produce such weapons would have been acquired by training with an expert and would have taken considerable time, probably years, to achieve.

The vast majority of bronze utensils would have been remelted and recast when they were no longer useful - due to breakage, wear or being replaced by an improved or more desirable design. Most tools would have been used until they no longer functioned. There are however some tools, particularly the more sophisticated metal workers' tools, including moulds cast in bronze, which seem to have been deposited before being worn out in a deliberate act of deposition. Such tool hoards, one of the most complete being the Roseberry Topping hoard now in Sheffield Museum, were often interpreted as the result of the deliberate hiding, with intention to retrieve, of a craftsman's tool kit. Certainly a set of tools for carpentry and probably also for metal working would have been required for any long journey where goods were transported by boat or wagon. Coombs (1975) however recognised the possibility that such 'personal hoards' may have represented the access of certain craft practitioners to the prestigious acts of deliberate deposition confined largely to the more elevated strata of society.

While it is probably true that all bronze production was circumscribed by ritual. It is clear that the form and function of the objects produced played a decisive role in which rituals applied, how the objects functioned symbolically and how all material culture remains appertaining to those objects were finally treated. It is not unreasonable to infer that the special nature of weapons manufacture and status of their makers, implied by the deposition of specialist tool 'kits', derives at least in part from the functional and symbolic importance of the objects made. The elevated status of weapon makers may well have been sufficient to ensure that any expert sword maker would have handed down his knowledge to the next generation either within the family or through other pupils, tied in some way to a particular 'workshop'.

'The tendency for specialist artisans to be both consistent and conservative in their work practices is well attested both in modern craftwork experience and in the historical record. The method of teaching by example, still used in apprenticeship, reinforces this tendency and means that a specialist workshop will often use the same processes over several generations, even when making objects which are far from morphologically identical. The almost total absence of decoration on the metal of British bronze swords means that there is no opportunity to use artistic comparisons to establish the work of individual sword makers' (Bridgford 1998, 207).

However the differences in microstructures identified by the characteristics investigated in Chapter 2.3 above do point to some element of regionality in techniques which may show the sort of continuity which would be expected from the passing on of techniques within a relatively closed group. Comparisons do need to be restricted to samples taken from the same position on the same category of weapon to ensure comparability given the clear differences between spearheads and swords noted in the majority of the characteristics discussed in Chapter 2.3.1-8, showing that, on balance, spearheads were less well made than swords. Thus the comparisons which follow have largely been confined to sword blade samples.

There is potential for considerable chronological overlap between different sword types, particularly when the swords come from different areas. There are indications, particularly in terms of trace element patterns as shown in Chapter 2.6 above, and variability in characteristics and dimensions, as shown in Chapter 4.2 above, that the Scottish and North Eastern Ewart Park swords may overlap chronologically with the Wilburton swords in the South and East. Furthermore the junction between different types within one geographic area can lead to hybrid types, such as some of the Blackmoor hoard (Colquhoun 1979), where continuity of practices would be expected to prevail despite differences in morphology. Confining the comparisons to particular typological groups may therefore be misleading in some cases although there are some types, especially the earliest and the Hallstatt influenced late types, which obviously fall so far apart chronologically that the concept of continuity in practices would be rather stretched to accommodate them.

Further consideration of the differences in working practices deduced from the microstructures of sword samples may provide insights into the pattern of production of these weapons. The differences according to typology, which may be related to chronology, must also be taken into account.

The early basal-looped spearheads, one from East Anglia and four from the South East, which were examined metallographically, showed clearly that both annealing and hardening procedures for weapons, most probably cast in clay moulds, were relatively sophisticated from the start of the period. Although the two examples from the West were virtually unhardened and exhibited a largely as cast grain structure, this may have been due to the position from which the sample was taken. If anything the lowland basal-looped spearheads were excessively hardened and, had the blade edges been subject to direct impact, they would probably have proved brittle. The one Scottish basal-looped example exhibited all of the characteristics of a burnt microstructure apart from the fact that the average grain size was marginally lower than the 35 micrometer threshold used herein.

There was more variation among the six Early swords in the South East; all were fully recrystallised but some were cored, grain sizes varied from medium to large and less than half could be described as excessively hard. The one Scottish and one of the East Anglian Early swords also showed medium hardness, grain size and coring but the other two East Anglian examples, both deposited in fens, had microstructures which fell into the categories denoting probable burning. In the West two of the four Early samples were effectively as cast, with only very minor hardening and one of these was definitely taken from the cutting edge, though this was nearer the hilt than was normally the case. The other two were both fully recrystallised and rather hard.

There is clearly no question here of the metal working techniques in place at the start of the period being in any way primitive; even the methods of ensuring that sword edges are not so brittle as spear edges appear to have been appreciated. There may however be some question regarding the consistency of finishing techniques applied to weapons deposited in the West.

There were no major differences in the distribution of metallographic features between the Wilburton and Ewart Park swords with the sole exception being the tendency to higher hardness in the Wilburton swords, a factor they had in common with Early weapons.

Regional differences were clear, both overall and within the Ewart Park sword samples considered separately. The Western samples showed higher porosity, larger grains and less microstructural distortion than other regions, indicating that much less finishing, especially hammering, was usually applied to the edges of Western swords, although this may be slightly overstated due to the presence of a some samples where the site is not necessarily the extreme cutting edge.

East Anglian Ewart Park sword samples were generally recrystallised but cored and showed the highest levels of microstructural distortion, both of inclusions and grains. They had low porosity, small grain sizes and relatively high and consistent hardness levels. South Eastern Ewart Park swords showed very similar characteristics, with small grains and a tendency to high distortion but with greater variation, more uncored and more unrecrystallised samples. A number of extremely high hardness readings came from this area leading to its having the highest average hardness.

The distribution of characteristics for the Scottish Ewart Park swords is rather more complex; microstructures are heavily concentrated in the fully recrystallised but cored categories, like those in East Anglia, and very few have heavily distorted grains, as was the case in the West, but the spread across the various inclusion distortion categories was more even than most as was the grain size distribution, although this was weighted towards the small and medium categories, b and c. The Scottish hardness levels showed a very wide range but the weighting was towards lower levels.

The range of characteristics seen within Scotland and the South East requires further investigation. As mentioned above, there may be a chronological overlap in Scotland with the Southern Wilburton traditions and it is possible that the greater range of some characteristics of manufacture merely reflects a longer time span, but this would not explain the concentration of others. However, an alternative explanation, that in such a large region we are seeing the results of more than one weapon making tradition, a supposition supported by the differential distribution of the heavy bladed Caledonian variant of the Ewart Park tradition (Colquhoun and Burgess 1988, 102-3) which is mainly confined to the 'Highlands and Islands', also fails to supply an adequate explanation for the concentrated distributions of some characteristics. Such concentration may stem from the longevity of certain regional preferences, in particular in details of annealing and final hammering of edges.

The relatively wide range of most characteristics seen in the South Eastern Ewart Park samples may reflect either or both of the above scenarios in that a number of the samples were taken from swords of the Blackmoor hoard, which has some Wilburton characteristics, thus the period covered is likely to exceed 250 years. It is also the case that some of the samples from this hoard, which comes from Western Hampshire, share a trace element combination with Western swords, showing that geographical differentiation in at least one element of weapon manufacture existed within the region. However there does seem, from the wide morphological variation of the weapons deposited in the Thames in all periods, to be a possibility that the South East was 'host' to deposition of at least some weapons manufactured outside the region, brought in perhaps by travellers attracted to the region by its continental orientation or to the Thames itself by a religious significance, which may once have approached that of the Ganges to modern Hindus.

6.3 Weapon Use and Warfare Patterns

Evidence for the use of weapons during the period is largely limited to that which can be seen in the weapons themselves. The difficulties experienced in isolating evidence of this aspect of the history of the weapon from subsequent events were discussed in some detail in Chapter 4. While it is clear that the majority of weapons did bear some scars which could reasonably be attributed to practical use it is unwise to be dogmatic about the cause of the damage on any one weapon and only the examination of relatively large numbers of weapons could lead to any confident assertions concerning the distribution of damage caused by use.

Another caveat should be made concerning the variation in distribution of such damage on a regional basis, since it does not follow that the damage seen was inflicted on the weapon within the region in which it was deposited any more than that the weapon was necessarily made in that region. Again, given sufficient numbers, the probability that this was the case increases, in the absence of any evidence to the contrary, but any conclusions reached concerning the practice of warfare within any region must be tentative, especially given the evidence for considerable inter-regional contact and the concentration of some forms of deposition in particular locations. Regional variations in depositional practice may well obscure the patterns of weapon use both locally and in other regions.

6.3.1 Combat Damage

The evidence for regional variation in patterns of damage to weapons attributable to their practical use was discussed in Chapter 4.2.4 above, for swords, and Chapter 4.3.4 above, for spearheads.

The swords deposited in East Anglia appear to have suffered more than most from deliberate damage inflicted before deposition but, since such damage could easily have obscured signs of the less invasive damage caused by edge to edge impact and since the proportion of East Anglian swords without edge damage is relatively low, it seems reasonable to assume that the majority had indeed been used for combat. The position is rather less clear for spearheads, in that use damage is even more difficult to detect but the two areas where it is most likely to show, the tip and the socket, seem to be rather less affected in East Anglia than in anywhere but the South East.

The Scottish data also seem to indicate that very few of the deposited swords had not suffered some damage consistent with practical use, though in this case there were relatively fewer where severe deliberate damage could have masked the evidence. The Scottish spearheads did show a very similar proportion which had suffered tip and socket damage but had rather more missing meaning that the proportion of undamaged spearheads, especially those with undamaged sockets, was rather lower than in East Anglia.

The weapons deposited in the South East, both swords and spears, had a very clear tendency to include a relatively high proportion of those with no sign of use damage, in all but the Wilburton sword group. However, even in the South East only around a quarter of swords showed no sign at all of damage which could have been caused by use, whereas over half of the spearheads failed to show any symptoms of damage due to practical use.

The Western weapons were rather too few in number to draw any but the most tentative conclusions but they had by far the lowest proportion of undamaged spearheads, although the swords were as likely as the Scottish weapons to have signs of use damage.

It would appear from the above that the South East may have differed markedly from all other regions in terms of the use of weapons or, at least in the history of the weapons which were deposited there. The tendency for Early weapons to be relatively undamaged is fairly universal but it is only in the South East that this seems to apply during the currency of the Ewart Park swords. It is tempting to see this purely as a difference in depositional practices; perhaps that the deposition of unused weapons remained a required part of a particular ritual in that area. However, the possibility that swords in particular functioned more as prestigious symbols than as weapons within the region cannot be entirely discounted. This may have been due to a relative freedom from armed conflict within the region, where the evidence, both of extensive overseas contacts and of considerable agricultural activity, as well as of artefact deposition, points to a relatively prosperous, well ordered community, probably widely recognised as capable of providing for its own protection from external threat.

6.3.2 Weapon Design

Further clues to the regional differences in the nature of weapon use lie in the design of the weapons. This is less useful to consider for swords since, as discussed in Chapter 4.2 above, the general design of the leaf shaped, integral hilted swords indicates that their purpose was to be used mainly as slashing instruments and that, not only was this true of all the types identified, but that, after the earliest types, the typological differences between different groups appear to have conferred little or no functional advantage, as was shown for the Wilburton and Ewart Park types by Brown (1982). The main grouping, the Ewart Park type, incorporates some of the smallest swords found and, on average, seems to have been somewhat lighter in 'feel' than the Early and Late varieties, indicating that it may have been a more utilitarian type than these others. This would only really have been noticeably beneficial in prolonged use, which may well have been a rather rare occurrence. It seems reasonable to conclude that the swords, when used in fighting, were used in much the same manner throughout the country.

Spearheads present a very different picture. The variety of types and sizes is very wide and some at least must have had special roles to play. Even accepting that a high proportion may also have been used in hunting and that some were probably used exclusively for that purpose, it should be possible to discern, within the undoubtedly regional distribution for certain types, that there was variation in use as well as stylistic preference.

The exceptionally long blades, those where the blade length exceeds 250mms or thereabouts (see Figure 4.3.1(v)), were most probably mainly used for show. They include a substantial proportion of the complex basal-looped spearheads, most of the complex flame-shaped blades, a considerable number of complex lanceolate blades and a few exceptionally long plain lanceolate blades (see Figure 4.3.1(ix)). It is noticeable that, if length is used as the criterion for assuming a 'display' purpose, many of the barbed spearheads fail to qualify, despite their interpretation as such on the basis of their long pegs and impractically short sockets (Burgess *et al.* 1972).

The obvious candidate for the universal multipurpose weapon must be the ubiquitous plain lanceolate spearhead. The development which led to the hollow cast versions of this weapon may, rather than having been an attempt to save metal, have been intended to lighten it sufficiently to enable its use as a thrown weapon in addition to the normal stabbing role. Certainly, among the complex lanceolate blades, those which are simply hollow cast with no other embellishment and those which are hollow cast with a single step just before the cutting edge, form the vast majority of the shorter blades. However, the resulting weapon would have been far from ideal for throwing and is likely only to have been used as such in the absence of a viable alternative. These hollow cast spearheads were the most common of the complex lanceolate group in both East Anglia and Scotland (see Figure 4.3.1(iv)).

Another complex spearhead type with a highly regional distribution is the multiple stepped spearhead. The vast majority of these come from the Blackmoor hoard in Hampshire and look like most impressive examples of the weapon makers' art. Whether their stepped surfaces perform any useful function is open to question. They are rather too large for any potential improvement in aerodynamics to be a consideration and the presence of lunate openings on two and socket decoration on one (Colquhoun 1979, Fig 4.1) does tend to emphasise the decorative aspect.

The most obvious candidate for use as a throwing weapon is the dumpy lanceolate blade. The rarity of metal arrowheads in the British museums' collections (Mercer 1970) is both notable and puzzling. The attribution of the beautifully made flint arrowheads to the Beaker period and Early Bronze Age means that either arrows were rarely used later or that they were tipped with material which has not survived or has not been recognised; perhaps simple sharp unworked slivers of flint served the purpose. The dumpy spearheads do not appear at all among the Scottish spearheads examined and only one had a Western provenance. They seem to have been largely confined to lowland areas of the South and East and were especially common among the South Eastern spearheads examined, which included the very large numbers from the Blackmoor hoard. Either dumpy spearheads were not in common use in highland areas or they were not deemed worthy of deposition, perhaps because their use involved little valour or prowess on the part of the individual.

Throwing weapons are of most use when there is a barrier to direct combat, such as a palisade, earthwork or stretch of water. When defending a place with the advantage of height it is relatively simple to lob missiles at an attacker but on level ground it is necessary to use weapons designed for the purpose since the energy requirement is no longer gravity assisted. Thus the presence of such weapons in areas with little high ground and wide navigable rivers is not surprising. Such air borne missiles are probably too heavy to be of use when attacking sites at the top of a steep slope, although arrows would be more viable. Both are absent from the areas which produced the early 'hillforts'.

The other spearhead type with a very clear regional distribution is the barbed (Burgess *et al.* 1972) which is most common in the areas of the West bordering the Welsh highlands and in the South East. The sites from which the South Eastern examples come do seem to be related to waterways. The Late Bronze Age 'Founder's' Hoard from Bramber in West Sussex, which contained nine examples, along with Watford type ogival bladed spearheads, numerous fragments and one specialist tool kit, lay under alluvium on the edge of the fllood plain of the River Adur (Bryant 1981). Many other examples, both from hoards and single finds are associated with the Thames and Kennet valleys (Burgess *et al.* 1972,220-1).

The large hoards from the Welsh Marches do not necessarily seem to come from such contexts but the Broadward hoard itself comes from a river valley at a place which is now a fairly major crossroads and the site from which it came was reported to yield vast quantities of animal bones, including skulls (Burgess et al1972, 212). The suggestion of ceremonial feasting or animal slaughter conferred by the bones within the context of the Broadward hoard may indicate that deposition of the weapons, which show many signs of burning, was associated with such a ceremony.

If, as suggested in 4.3.2 above, this weapon type did have a practical role in terms of attacking thatch, wattle, brushwood or textile with fire, it may have been used against waterborne transport or against occupation and 'gathering' sites, such as at Reading Business Park and Runnymede, which appear to have proliferated along the major rivers at the time.

It is hard to explain the relative absence of this type in other areas. Again it may be a case of 'unsuitability' for deposition rites. Possibly, if the type was purely a display weapon, it did not perform this function elsewhere. More mundanely it may have been unsuitable for practical use elsewhere; defences of earth and stone or roofs of turf, for instance, would be impervious to the effects of fire.

The distributions of other types of spearhead are not markedly regional in nature, thus any differences in the use for which they were designed is unlikely to throw any light on regional differences in the way they were used. However the position of the ogival spearheads is interesting, in that, although they form a part of the Broadward tradition (Burgess *et al.* 1972), their distribution is widespread and not restricted to any one region. Their purpose is unclear; they are not large but many possess incised decoration. There is no obvious utilitarian need for their unusual outline, whether it is of the more extreme sinuous type or merely features a change from convex at the blade base to a straight mid section and a relatively abrupt tip. The lack of impressive length probably precludes any 'parade ground' function, but whatever role they played in society, as ceremonial or personal weapons, it was clearly one which applied in all regions. The one sign of regional differentiation within the type is the somewhat larger size of some Scottish examples. This, in itself, may point to a use in hunting, with the typical prey in Scotland being rather larger than elsewhere.

6.3.3 Topography, Travel, Land Use, Settlement and Warfare

One of the most salient features relating to the practice of warfare on any scale is the topography of the area in which it takes place. This also dictates routes of travel, land use and settlement positions. Examination of how these factors inter-related should help to provide physical settings for the social contexts within which people lived.

The different regions used in this study were, as discussed in Chapter 1.1.4, largely based on the obvious differences in physical geography between them and on the use of the coastal waters and river systems for transport of goods and people. These river systems also seem to have dictated the settlement pattern which emerged in the Middle to Late Bronze Age. Rescue excavations along the Thames basin have revealed settlement sites of the period on the first river terrace, often covered by substantial alluvial deposits. Some sites in the upper Thames region, such as Yarnton, appear to have been 'decommissioned' with deliberate blockage of water holes at some point in the Late Bronze Age or Early Iron Age, while others, such as Eynsham Abbey were re-occupied at the end of the second millennium (A Barclay & A Cromarty, paper given at 'Place and Space in the British Bronze Age', Cambridge April 1999).

There exist extensive field systems, similar to those which Pryor (1998) has interpreted as used for animal husbandry, which are grouped, with seemingly 'open pasture' between. These field systems coincide with settlements and concentrations of river deposited metalwork in areas such as Lechlade and Wallingford and, on the other side of the Goring Gap, Marshall's Hill and Runnymede-Petters. Wallingford and Runnymede both feature island settlements and all but Wallingford have circular enclosures or 'ring forts'. Similar patterns of concentration appear through Surrey, Sussex, Greater London and into Kent and Essex, Examples include sites, some of which have already been identified as possessing 'ring forts' (Needham 1990) as at Mayfield Farm (near Heathrow), Queen Mary's Hospital (Carshalton on the River Wandle), Highstead (Kent), Coldharbour Road (Kent), Mucking (Essex) and two major sites still in the process of excavation on the Isle of Thanet (Yates, 1998, and paper given at 'Place and Space in the British Bronze Age', Cambridge April 1999).

Similar field systems occur along the gravel terraces of major river systems in Cambridgeshire and, although settlements identified as of the Late Bronze Age are more sparse, they do tend to be connected with concentrations of metal deposition (T. Malim, paper given at 'Place and Space in the British Bronze Age' , Cambridge April 1999 and PPS in prep.).

All of the recent research tends to emphasise the importance of rivers and riverside land exploitation during the later Bronze Age. The concentration of settlement is clear from sites such as Reading Business Park but it is also clear that the island sites with their 'wharfs' and palisades (as at Runnymede) and causeways (as at Wallingford) may have been more important in terms of their function as meeting places than just as settlements or riverine 'ports'.

The function of the 'ring forts' remains equivocal. Many are very closely situated, Mucking has two, not necessarily contemporary, examples less than one kilometre apart, and the 'defences' they possessed do not convince as military fortifications but their situations, generally using landscape features with an extensive view along the valley, indicate that they could have assisted in 'controlling' and monitoring access to and through the region. Most had few buildings but at least one, usually impressive, building was contained within the enclosure and there was a wide variety of 'foundation deposits' at entrances, ranging from human cremations to clay mould fragments (Needham 1990 71-3).

It is entirely possible that each had a different function or that most served a variety of purposes for the associated settlements. However, all seem to incorporate an element of separation and exclusion of at least some elements of the community. The lightness of the 'defenses' indicate that such exclusion was consensual, at least within the locale, and that any military use, as indicated by the sword moulds at Springfield, was not that of an 'occupying force'. The context is consistent with intermittent use, probably with considerable ceremonial, by an elite group, whether or not it was a ruling elite, which may have been responsible for safeguarding the interests of the people of the area, in terms of security as well as less mundane matters. The ceremonial practices probably, as in all activities, had considerable religious significance but dealt with issues which demanded that only certain elements of the population be present, unlike the site at

Runnymede, whose massive 'domestic' deposits, apparently including feast remains, indicates an influx of large numbers of people from outside the immediate site area.

It is tempting to interpret Springfield, with its sword moulds, as the meeting place for males belonging to a warrior group but, if the foundation deposits elsewhere reflect the criteria for inclusion, the range could be very wide. Human remains may indicate that there was an ancestor, a revered 'ruler', a symbolic 'martyr' or even a fallen enemy, which the group held in common. Animal bone deposits may have reflected the identification of the group with an emblem or deity, as in the particularly exclusive 'orders' of the Jaguar and Eagle seen in Aztec sites like Malinalco on the Mexican central highland plateau. They could, more mundanely, indicate the importance of the animal type in the economy of the population being served or they may have been the remains of the foundation sacrifice or feast.

Warfare in these lowland riverside areas may largely have been confined to ensuring that the community was protected from outsiders who were unaware of, or unwilling to abide by, the procedures by which meetings, exchange, rituals, ceremonies and daily life were normally organised. The resident populations appear to have been relatively affluent and settled with considerable cultural affinity and little conflict existing between neighbouring groups. Although such affluence is likely to have attracted some raiding activity, the existence of mechanisms to ensure that it did not escalate would have been in the interests of all. Clearly the local population would have outnumbered any long distance incomers and conflicts should therefore have been short lived and small scale. The existence of an accepted system of selecting leaders, whether by age, interpretation of the wishes of a deity, inheritance, election, individual prowess in combat or any combination thereof would have mitigated against any major internal armed conflict, although an occasional challenge to the accepted order cannot be ruled out. It is highly probable that those who travelled outside their local area did so in groups with at least some, if not all, being armed and that this would be essential when carrying valuable goods.

The emphasis on rivers as a means of transport is less obvious when considering the highland areas *per se* but travel from these areas towards the South and East means that the river systems would have been used from the points where the flow became navigable along their entire length. Some intermediate areas on the chalk uplands, which had shown considerable exploitation in earlier periods, showed little concentrated settlement in this period. The Wessex grasslands were showing signs of ecological stress by the Middle Bronze Age (Lawson - pers. comm.) unlike those of the Thames area

(Yates - pers. comm.). The sea itself would have provided links between coastal areas and the lands surrounding the major river estuaries must have seen considerable activity. However, excavations within the heavy alluvial silts, such as those at Cabot Park Avonmouth and others, such as Chapeltump, Rumney Great Wharf and Cold Harbour, along the Severn foreshore are revealing sites of seasonal activity, including 'industrial' activities such as salt making, rather than the round house settlements of drier locations (M. Locock, paper given at 'Place and Space in the British Bronze Age', Cambridge April 1999). It would seem that the lower reaches of the Western rivers were less well suited to permanent settlement than the Thames gravels.

Exploitation of the highland landscape during the period included the foundation of a number of 'hill forts' some of which later developed into massively defended hill top fortresses in the Iron Age. Harding's (1976, 35-38) volume opened up the subject of Late Bronze Age origins in discussing the radiocarbon dates, the existence of early pre-rampart defences and the presence of undefended 'settlements' at a number of sites, especially in North East Wales. Similar dating exercises in Scotland, on the 'vitrified forts' in the same volume (MacKie 1976, 224-226) showed that a number of these could also date back to the Late Bronze Age. The more recent work on dating and excavation of hillforts, discussed in Chapter 1 has confirmed these conclusions and has given us a number of hilltop sites securely dated to the Late Bronze Age which were occupied in the period, some of which may have possessed structural defences.

The early site at Rams Hill (Bradley and Ellison 1975) in Oxfordshire has multiple entrances, reminiscent of the 'ringforts' and shares with them the ability to overlook major 'through' routes. The early hillfort site at Beeston Castle, illustrated in Plate 6.3.3, is virtually inaccessible, on a rocky outcrop, overlooking, some 100m below, the Mersey estuary to the North, the River Dee and Wales to the West, the Wrekin to the South and the Peak District to the East. As an early warning and monitoring position it could not be bettered and even its natural defences are sufficient to discourage most (Ellis 1993, 13). Dinorben occupies a promontory position looking out over the plain near the mouth of the River Clwyd (Savory 1976, 244). 'The most striking feature of...the Breiddin Hill...is the drop of up to 300m to the valley of the River Severn to the North-West' (Musson 1991, 7). The site of Sheep Hill, which yielded mould fragments for a bronze axe and a spearhead from a sub-rampart midden, overlooks the River Clyde about 10 miles West of Glasgow (MacKie, 1976, 211-214) and Traprain Law (Cree and Curle 1922), with its own bronze working mould material, including part of a sword mould, overlooks not only the valley of the Scottish River Tyne but commands the plain at the South of the Firth of Forth.

Common to all of these sites is the use of the landscape to oversee major routes of travel, by river and by sea, in an exaggerated version of the lowland enclosures. The inaccessibility of some sites may well have precluded any need for enclosure to keep others out and could indeed have provided a challenge sufficient to test those seeking to 'belong' to the group. It is true that traffic other than that related to metal production must have used the routes concerned but it is hard to ignore the position of a number of the earliest examples in control of the routes leading from the areas containing Bronze Age copper production to the centre of the country and to the coast. Such sites would not have been used on a regular basis by those coming from outside the area but could have been used to monitor their movements. Equally it is highly unlikely that outsiders would have 'prospected' for metal on the basis of occasional visits of short duration. Any visitors wishing to obtain the products of the region would be much more likely to have brought exchange goods with them and would undoubtedly have come prepared for any trouble which might arise.

The lack of weaponry deposited in the majority of the extreme highland areas of the West may show that weapons were too necessary to be deposited or that few possessed the wealth required to command the skills of the weapon maker (a point perhaps also seen in the somewhat lower quality of the Western sword samples examined and discussed in Chapter 2 above). The deposits of metal work at the foot of some hillforts, such as Dinorben, may have been made to 'buy' the right to pass from the spirits of the place. However the peculiar positioning of a few deposits in the mountains may indicate a difference in the siting of venerated places; a tradition of deposition in passes has been seen in other mountainous areas, such as South Eastern Spain. The lack of deposits could even be due to the practice of depositing bronze at all being an entirely external custom indulged in only by outsiders.

6.4 Weapon Deposition - Regional Variations

It is difficult for members of a modern urban populace to comprehend the essential indivisibility and intertwining of all aspects of daily life and religious beliefs for the vast majority of people even in medieval times but the problem of such incomprehension is a very recent and culturally specific phenomenon. The likelihood is that the people who deposited bronze and other specific articles of their material culture throughout the Bronze Age did not differentiate at all between 'normal' and 'ritual' acts. Even some aspects of ritual, such as the performance of prescribed chants during a particular activity, which may well have had practical value, such as limiting accurately and consistently the time consumed by the activity, do not require that the practitioner be at all aware of our perceived practical application. It would suffice to know that the chant was performed because the action and the chant went together, always.

The practices of weapon deposition, discussed in Chapter 5.2 above, and their social contexts, discussed in Chapter 5.3 above, show considerable regional variation. The extent to which the context of deposition and the treatment of the articles prior to deposition depended on the connection between the objects and particular people or events or the particular symbolism of the object cannot be known in detail. The more the contextual detail of excavated sites becomes known the less evident is an attitude towards 'rubbish' deposition which is in any way whatever related to the modern landfill site. Depositions seem to mean something to those depositing and to those seeing the act or its result. Structured deposition does not seem to require articles of any obvious value. There seems to be as much meaning in how and where things are placed as in what they were, though what they represented may have been more important than any commercial value which we might perceive. In a society where bones and broken pots were deliberately buried in individual pits, the deposition of bronze items, now described as scrap, may possibly have been accidental but is unlikely to have been an act of wanton abandonment of the 'valueless' items within. It is entirely possible that breaking weapons changed the nature of their meaning and the treatment prescribed for their disposal. It may even be that weapons thus treated lost their power and became 'safe' to deposit in a particular way.

It is difficult to envisage a context in which recognisable weapons are divorced from a symbolism of combat and warfare and the deposition practices in which they featured must have dealt with this aspect as well as other, perhaps more personal, connections. As symbols of power and status, weapons, especially swords, have retained some echo of their past meanings even to this day. It is not unreasonable to assume that the regional differences in deposition of weapons may indicate a difference in the way that the people depositing them viewed and dealt with violent conflict.

Deposition of burnt and broken weapons, as discussed in Chapter 5.3 above, was a relatively rare event but the major instances seem to have taken place in at least three of the four regions examined. If they did result from an individual and large conflict or the demise of a major figure, the symbolism involved was expressed in the same way throughout. The inclusion of several burnt pieces within the Waterden hoard may have been accidental. They, as in the other major burnt depositions, may have been destined for a traditional 'wet place' deposition, with the unburnt pieces, which form the vast majority, being consigned to a dry location, perhaps overlooking the scene. There is one spearhead sample, supposedly from the Wilburton hoard, which does not exhibit the burnt microstructure of all the other samples taken from that hoard and this may be a case of the reverse of the same process.

The similarity through time of the deposition practices relating to spearheads, rapiers and swords indicates that all could contain elements of the same symbolism. The relative concentrations of the weapons may well, as has generally been assumed, reflect the prevalence of their use rather than any difference in meaning of the deposit but the possibility that this is not so should not be ignored.

The major regional differences in depositional practices lie between the lowlands, with their rather spectacular quantities of deposited weaponry, often, once the Wilburton metal work is introduced, in a broken or, later, fragmentary state. and the highlands, especially of the far North, with their relatively smaller deposits of, often complete, swords from contexts which need not necessarily have been wet.

This could be interpreted as indicating a very different attitude towards weaponry. While , initially at least, seeing weapons as highly prestigious objects, the culture of the South and East could be also be viewed as treating weapons as a representative of something which should in general be feared and requiring 'neutralisation' by the deposition rituals, a tendency which seems to increase with time and increasing prosperity within those regions. The deposits of the North could show a much more 'comfortable' and personal relationship between a warrior and his weapons with the deposition ritual being related strongly to the person concerned, even though major events demanded rituals in line with those used for the same occasions elsewhere in the 'soft South'.

7 Summary and Conclusions

This research project was designed as a large scale detailed study of swords and spearheads, of the period from approximately 1250-750BC, which were deposited all over Britain. The chronological scheme used is that put forward by Needham (1997) and outlined in Figure 1.2. This framework incorporates the sequence defined by metalwork typology, which is heavily influenced by widely accepted typological groupings of swords, whose chronological sequence is well defined in the South East of Britain. The types include a wide range of Early swords, which pre-date 1150BC, and the Wilburton type, which is largely confined to the South and East of the country and covers the period 1150-1000BC. The Ewart Park type follows on from the Wilburton type in those areas where the latter is usually found, and may have continued until around 750BC. There were a limited number of Late types, including the Carps Tongue and the 'Gundlingen' types, which appeared later during the currency of Ewart Park types, with the former appearing rather earlier than the latter.

The work done for this project has, it is hoped, opened up and developed methods of studying artefacts which may expand our understanding of other spheres of life. The use of small solid samples for metallographic and other analysis, as advocated by Northover (1989), has proved both feasible and valuable in establishing manufacturing methods for swords and spears and, given a large number of samples, has proved capable of producing meaningful information when results are analysed statistically. The need to know the microstructure of the ancient metal and to replicate this as well as the chemical composition and relevant morphology of the artefact has been underlined by the edge damage replication experiments.

The experimental approach to reproduction and to 'use wear' has itself proved worthwhile in establishing, for sword edges, the morphology typical of combat damage. The use of experimental results for similar purposes has, indeed, proved worthwhile for others, e.g. Fasnacht (1998), in establishing casting techniques, and Kienlin & Ottaway (1998), in establishing surface markings on axes caused by use in woodworking. Experimental work confers advantages far beyond the ability to answer questions concerning the technology of how artefacts could have been made and used and what the results would have been. The direct experience of working with the same materials, and some of the same problems, is the closest that one may come to sharing in and understanding a few of the experiences of the people who produced and used the artefacts now so securely treasured within our major institutions

The decision to combine results from the metallurgical analyses with the typological evidence followed the example set by Needham (1991) in his study of the Petters hoard, although the scope of the evidence examined and the topics addressed were rather wider. While some of the findings concerning weaponry had been noted or suspected before it was only the examination of sufficient numbers of samples and weapons undertaken herein which could facilitate the statistical analyses to assess whether or not the differences seen were significant and to establish the likely distributions and ranges of the characteristics examined.

The results of the research project were interpreted, in conjunction with the existing body of evidence, produced and interpreted by several generations of scholars, concerning many aspects of how people lived in this island during the period from 1250-750BC, in order to elucidate practices of and attitudes towards weapon makers, weapon users and warfare and to set these within their social contexts, building on the approach advocated by Coombs (1975a) in his study of British Bronze Age weapon hoards.

7.1 Metallurgical Analysis - Weapon Production and Weapon Makers

Results from a variety of analytical methods were combined in order to derive the maximum of information from the weapons examined. The first approach used was to examine in detail the metallurgy of the weapons. Very small solid metallurgical samples were taken from 72 sword edges and 1 spearhead edge and a further 74 sword and 55 spearhead samples, the majority also from the edge, which had been used for previous studies of metal composition, were borrowed from Dr J P Northover.

The chemical compositions of the samples were ascertained using EPMA. These compositional analyses showed that the average tin content of the alloy used was approximately 10% and that the majority of the blade edges contained less than 1% of lead and less than 1% of trace elements, neither of which would have had any effect on the 'workability' of the metal. There were variations in trace element patterns which seemed to be chronologically determined with the basal-looped spearheads tending to exhibit the typical arsenic/nickel and arsenic trace element patterns of the Middle Bronze Age, while the Wilburton weapons and some Early swords showed a high trace element total with nickel, silver arsenic and antimony all present, as did a number of the Scottish Ewart Park weapons. Most Ewart Park weapons tended to have much lower levels of impurities and this trend applied also to the Late weapons.

Four very large cross sectional samples, taken some time ago from swords of the period, were borrowed, three from the British Museum and one from the Royal Armouries. These were examined metallographically to indicate how the manufacturing processes affected the microstructure of the entire artefact. The cores of the cross sections showed that there were differences in the quality of the four castings, with variations in the type and quantity of porosity. However, all four showed that the post casting treatments were largely confined to the outer surface and that only the blade edges had been extensively cold worked. Heat treatments on all four had failed to penetrate to the core of the casting, indicating that they were of relatively short duration.

All the small samples were examined metallographically to show the effects of the processes used to finish the edges of the weapons. The results were analysed statistically according to regional and typological groupings. The metallographic examinations showed that some porosity was visible in the majority of samples, despite the fact that almost all had been hammered, but in around 15% of samples it had effectively been closed up by the hammering. The more severe levels of porosity tended to be less common in swords than in spearheads. Almost all of the samples contained copper sulphide inclusions which had been directionally deformed by hammering, although rather more spearhead than sword samples had inclusions which were totally undeformed. The percentage deformation undergone by the sampled area in the most heavily worked cases was probably in excess of 80% and this extreme level of deformation was much more common in swords than in spearheads. Experimental work, discussed in Chapter 3.1, showed that, although difficult, it was possible to achieve high levels of deformation despite inadequate annealing.

Over 80% of the samples showed areas of high tin delta phase or alpha plus delta eutectoid, although almost half of these had very little. The presence of these high tin areas, when combined with incomplete recrystallisation, as shown by 15% of samples, or residual coring, as was present in 75% of samples, shows clearly that annealing was generally too short and at too low a temperature to homogenise the metal, even within the worked edges.

Only 8% of samples had the large uneven grains which showed that there had been no heat treatment after casting and the majority of these were samples from spearheads. The grains in most other samples had the regular edges and annealing twins, which are indicative of heat treatment leading to recrystallisation, and were much smaller. Spearhead samples tended to have rather larger grains on average than comparable sword samples, which, in conjunction with the other microstructural evidence, indicated less cold work prior to annealing for spearheads than for swords.

Some 16% of the samples examined were fully homogenised with very large even grains and annealing twins. This microstructure shows excessive heat treatment and given that it is not only too 'soft' for a weapon edge but can be rectified if produced accidentally, it is not likely to have resulted from the manufacturing process. These weapons were clearly 'burnt' at some stage after manufacture and most appear to have been deliberately destroyed prior to deposition.

The vast majority of the samples did show some distortion of the grain structure as a result of deliberate hardening although relatively few were very severely distorted. The hardness values provided a quantitative indication of the severity of this final post-annealing deformation and the analyses indicated a complex distribution with very low hardness levels being found in samples with a typical 'burnt' microstructure. As discussed in Chapter 2.3.8 above, the distribution of hardness values showed a central group of grain distortion, which accounted for the bulk of the samples, possibly incorporating three overlapping populations. There was also a smaller group of very hard samples, which probably exhibited a desired rather than an accidental outcome.

Most of the information concerning manufacturing techniques was derived from the metallographic examinations, discussed in Chapter 2, but this was considerably expanded, and slightly amended, by the experience gained while producing the experimental edge sections. Furthermore some 499 swords and 485 spearheads of the period, representing 34% and 23% of the respective total known extant populations as estimated in Chapter 1.6, were examined visually, with the aid of a bench microscope, and photographed. The data recorded included characteristics related to manufacturing quality, such as porosity, surface quality and edge finish.

The assessment of manufacturing quality by means of a subjective appraisal of the actual artefacts, discussed in Chapter 4, was inevitably less precise than that provided by examination of the microstructures but, not only did it broadly confirm the microstructural findings, it also provided a larger data base from which to analyse the regional and typological variations statistically.

The metallographic examinations showed that the majority of sword samples were probably fairly sound castings and that almost all had been hammered, many being severely deformed, and annealed for short times at low temperatures. Most had been hammered again after the final anneal to increase their hardness. The quality of sword manufacture was extremely good and astoundingly consistent and the information from visual inspection alone underlined the consistently high quality of the swords. There seems to have been adequate control exercised over the hardness and toughness of the finished edge and this indicates that a fairly sophisticated appreciation of the qualities of the alloy and how to change them was within the range of at least some metalworkers.

The proportion of spearheads whose quality on visual appraisal could be described as poor, approximately one fifth, was greatly in excess of that for swords, which is entirely consistent with the metallographic results. The need for tough and relatively hard edges is much less marked for spears than for swords, thus it is not surprising that spearhead edges are generally less heavily worked, but the variation in the quality of casting of spearheads, which is just as critical to performance as it is for swords, is an indication that some at least were not made with the same expertise as swords.

The differences between the swords and spearheads in the range of techniques used raises some interesting possibilities concerning specialisation. There may only have been a few 'workshops' capable of producing swords and the longest spearheads and these may have either only made such items or have produced most artefacts to a high standard, with some, where the quality was less critical, being cast or finished by 'apprentices'. Other, less skilled and probably more numerous, artisans may have produced a range of smaller castings, including some spearheads and axes, to a lower standard. The sword makers would necessarily have become skilled in the use of clay moulds, as described in Chapter 4.1.2 above, since these were used to produce the finest artefacts, and would have required considerable training, building up the experience and the skills needed, for both casting and finishing, over time.

There are some indications that the tools of skilled metal workers could be deposited with some ceremonial, similar to that accorded to some of the weapons they produced, as displayed by the deposition of individual tool 'kits', such as the Roseberry Topping hoard. Indeed the production of weapons may itself have had a ceremonial aspect in terms of its location, as described in Chapter 6, either within enclosed areas, as at Beeston, Cheshire, and Mucking, Essex, or in isolated spots, as at Dainton, Devon, and Tewkesbury, possibly with accompanying feasting, indicated by the burnt stone mound at Sandy Lane, Charlton, Glos. and structured symbolic deposition of its 'debris', as shown by the sword moulds at Springfield Lyons, Essex. Details of such activities also appear to have varied regionally as did the stylistic and technical influences which affected weapon production. The overall impression that the weapon makers were treated with some respect is, nonetheless, universal.

In addition to providing the anticipated information concerning manufacturing techniques, the metallographic examinations shed new light on the treatment of certain weapons before deposition. Not only did it show that a very different microstucture was present in those samples which were cut from weapons showing obvious external signs of burning but it showed that a small number of weapons had been subjected to similar procedures despite showing no superficial evidence thereof. The pattern of corrosion penetration in such samples also indicated that they had been burnt before deposition which, although obvious in cases found in rivers and lochs, had been debatable for others, particularly the Wilburton hoard, whose state was attributed to peat burning many centuries after deposition (Evans 1884). The weapons which had been burned were also largely broken up and deposited in a manner which suggests that the observed burning formed a part of a destruction ritual, whose form was prescribed by society to mark a particular type of event, such as, perhaps, the death of a leader or a major victory.

7.2 Experimental Impacts - Combat Damage

Using the manufacturing techniques which were evident from the samples examined, sections of 'sword edge' were prepared and impacted experimentally to reproduce the types of edge damage which would have been caused by use in combat. The force used was comparable to that which would be experienced in combat and the angles of impact were varied to reproduce the types of impact observed in sword fights.

The experimental impacts, discussed in Chapter 3, showed that the type of damage seen on the edges of most swords requires a severe impact with material of equivalent hardness. Wood, hide and fresh bone, if sufficiently thick, were found to absorb a heavy impact, despite being cut, without any perceptible damage to the metal edge. The morphology of the damage caused by edge to edge impacts varied with the relative hardness and fineness of the two edges and, even more obviously, with the angle of impact. However, it was clear that the damage which would be caused by a much thicker hardened blade, such as an axe, or by striking the blade against a rock, would differ from the range seen both in profile and dimensions.

The edge segments were photographed before and after impact to provide a set of examples against which damage visible on the edges of Bronze Age swords could be compared.

Ancient damage to the edges of those swords examined, which were sufficiently uncorroded, was analysed and attributed either to practical use or deliberate destruction. Only a quarter of the swords were effectively free from edge damage. Since not all of these swords were complete and since minor edge damage caused by combat may well have been removed by regrinding, it is possible that some of these may have been used in combat at some time. Combat damage was readily identified on over 50% of sword edges, courtesy of the experimental results described in Chapter 3, and this did not include those which had suffered the very severe damage, indicative of deliberate destruction, which would probably have hidden any earlier combat damage.

Although the tip and socket damage seen in spearheads is less securely tied to fighting, the fact that over a third of spearheads had tips and over half had sockets which were either damaged or missing would indicate that a substantial proportion probably had seen combat.

7.3 Weapon Design, Use, Decommissioning and Deposition

Statistical analyses of the dimensions and morphological features of the swords examined, discussed in Chapter 4.2.1, confirmed the relevance of most of the established typological groupings, which were described in Chapter 1.2. They emphasised the closeness of the Wilburton and Early groups, which is in line with the revised dating of the former (Needham *et al.* 1998), and the non-sequential and, therefore, probably intrusive nature of certain characteristics of the Late group.

Although some spearhead types, such as the plain lanceolate, were clearly present throughout the period, others have, as demonstrated in Chapter 1.2, been more precisely placed within the chronological sequence. The basal-looped spearheads, which often feature angular midribs and flame shaped or triangular blades, are early, while hollow cast spearheads appear, with the Wilburton phase, by around 1150BC. The barbed and ogival spearheads, which are often found with Ewart Park or Carp's Tongue swords, seem later again (Burgess *et al.* 1972, Coombs 1975, Ehrenberg 1977, Coombs 1979, Needham *et al.* 1998).

Quantitative analysis, discussed in Chapter 4.3.1, showed clearly that complex spearheads, other than the simple hollow cast types, tended to be larger than plain ones. Barbed spearheads could readily be quantitatively differentiated into the short wide bladed and the long narrow bladed types already identified (Burgess *et al.* 1972), while ogival and dumpy spearheads displayed a very narrow range of dimensions.

British Late Bronze Age swords are remarkable for their lack of decoration which indicates that any decorative devices used were confined to hilts and scabbards. The few exceptions had very limited decoration and often had clear continental affinities. Incised decoration was less rare on spearheads but was overwhelmingly confined to the ogival type.

In terms of design for utility, all but the very earliest swords have hilts designed to provide strength when used in slashing mode and the ubiquitous leaf shaped blade is also well suited to this purpose. The Wilburton group were on average 'lighter' in balance than Early swords, making them easier to use, but this 'native' tendency was more extreme among the Ewart Park swords, which, when handled, feel much better balanced than other types. The Late swords were much closer to the Early types in balance than to either of the two clearly indigenous types.

Despite these differences, there would have been little real variation in the manner in which swords were used for combat and the proportions exhibiting combat damage are very similar for all the sword groups, although the Early swords do have a significant tendency to be deposited undamaged. This may reflect the relative rarity of Early swords, the ownership, and deposition, of which might have been largely confined to those who were less likely to participate personally in actual combat, thus emphasising the prestigious nature of the swords rather than their utilitarian purpose.

Dumpy spearheads were clearly the best designed for throwing, although stabbing use remains feasible. Although the largest versions of the barbed type might well have been used for display as suggested by Burgess *et al.* (1972), the design may have had a practical purpose. Barbed spearheads with their very shallow sockets could have been used to anchor flaming material firmly to thatch or wattle, in which case the weakness of the shaft joint might even have been advantageous, as it could prevent use of the shaft in removing the spearhead. They share with the ogival Watford type the rather abrupt point which indicates that their function differed from that of the more normal long pointed spear but their generally poor quality of manufacture contrasts strongly with the well made and often decorated ogival spearheads

The typological pattern of damage for spearheads did not indicate any substantial dependence on chronology. The ubiquitous plain lanceolate spearheads had a relatively low proportion of undamaged examples while the ogival and dumpy groups exhibited high proportions of undamaged spearheads. This may again point to a less practical function for ogival spearheads but for dumpy spearheads it is probably because they are intrinsically very robust.

Most evidence from the period indicates that combat was generally conducted only on a small scale and that wholescale killing or displacement of entire groups of people did not take place. However, the fact that the weapons themselves were made and the forms that they took clearly indicates, as discussed in Chapter 5.1, that group combat did take place and that, even by the time the slashing swords were adopted, it was endemic. Clearly both swords and spearheads had a practical purpose and the evidence provided by the damage to those which were deposited shows that most were used in combat. The few very large weapon hoards found may give some idea as to the size of a 'major' fighting unit and, if this is the case, such units were relatively small, with between 35 and 75 warriors armed with swords or spears and possibly others armed with axes or other weapons. This again indicates that warfare was not on a scale compatible with 'total' war or mass invasion but probably took the form of minor skirmishing with the occasional, but rare, 'pitched battle' between relatively small groups.

Evidence of deliberate destruction was shown by damage to, breakage and burning of weapons. In addition to 'decommissioning' damage from destruction of sword edges and brutal removal of spear shafts, causing socket and midrib damage, many weapons were deliberately broken up before deposition; some into fragments which may possibly have been intended for recycling but many into pieces too large for remelting.

The edges of Early swords deposited tended to show less 'decommissioning' damage than expected, while the later indigenous Wilburton and Ewart Park swords had suffered relatively high levels of deliberate hacking. The small group of Late swords examined were just as likely as the preceding indigenous types to have suffered 'decommissioning' damage. A similar pattern applied to breakage with a high proportion of Early swords being complete, while Wilburton swords tended to be broken into substantial pieces with Ewart Park swords tending more to fragmentation. Evidently the deliberate destruction of swords was less common before 1150BC than it became later. Spearheads in general were less likely to be incomplete than swords, but the plain lanceolate spearheads were less likely to be complete than others.

The identification of deposition in 'watery' contexts with 'ritual', based largely on contemporary descriptions, by Caesar, in his reports of the Gallic Wars, among others, of 'Celtic' Iron Age ceremonies where booty and captives were 'sacrificed' (Coombs 1975, 70), seems incontrovertible, although this in no way precludes ceremonial deposition in dry contexts. The existence of similar customs in the Bronze Age is entirely in keeping with the evidence of deposition seen. Indeed weaponry had its own set of ceremonials, mainly exhibited in deposition rituals, long before the half century considered here. Even during the Mesolithic flint axes were deposited in the Thames (J Cotton - pers. comm.) and the deposition of fine weapons, many, such as polished stone axes, more decorative than practical, continued through the Neolithic (Bradley 1990, 67) and Bronze Ages.

The rituals of weapon deposition were more complex than any simple equation of wet context and ritual deposition would indicate. The type of damage seen was analysed in conjunction with the physical context in which the weapons were deposited in order to assess the manner of their 'decommissioning' and deposition and it was clear that no combination of edge damage, breakage, burning and physical context could be excluded, although some processes were more commonly combined than others.

The context of weapon deposition was in general almost equally as likely to be recognisably wet as not but in the first half of the period the tendency for wet context deposition was decided. There was a correlation, between completeness and wet context, and fragmentation and 'dry' context, among the Ewart Park and Late swords, which may have been present throughout but could have been masked by the much lower incidences of fragmentation and of 'dry' context deposition in the earlier period. A similar correlation is seen within the group of plain lanceolate spearheads but the opposite seemed to be the case with complex lanceolate spearheads. This may indicate that not all of the complex spearheads were being treated as 'normal weapons' for the purposes of deposition rituals.

It is clear that there were chronological trends in weapon deposition; at the start of the period considered here it would seem that more pristine weapons were preferred for riverine deposition but that the requirement for weapons to be burnt, hacked or broken up before deposition became a more important factor as time progressed. Evidently the weapons deposited were not intended to be retrieved and re-used. Deposition in shallow water, as at Flag Fen, took place regularly, indicating that the social context of deposition prevented retrieval from such accessible deposition locations. Perhaps the force of this prohibition became less pervasive with time and the need to 'decommission' before deposition therefore grew. However, such changes are just as likely to indicate that the ceremonial concerned served a different purpose, the frequency of which increased with time and which required that weapons of, say, the enemy or of the dead be themselves destroyed before they could be committed to a sacred location. Such activities differed both in frequency and in detail of the procedures followed, according to region, but it is evident that, even within a particular region, various ceremonials of weapon deposition took place concurrently.

Weapons seem to have had many symbolic roles in addition to their practical functions. They probably served to show the existing status of, or even to confer status upon, individuals and specific groups of people and appear to have played their part in death ceremonials (Bradley1990, 99-104) as well as in making sacrifice to propitiate or give credit to the gods and ancestors. They also functioned as symbols of conflict and of warfare and some of the ceremonies in which they featured must have served to negotiate the ambivalent relationship between society and warfare.

7.4 Weapons, Warfare and Warriors in their Social Context

The weapons of the period were sophisticated both in manufacture and design, the people who produced and used them are unlikely to have been less so. The propagation of knowledge and organisation of the practical necessities in a non-literate society probably require greater sophistication, and certainly demand more of the individual's mental capacity, than when written records are available. The weapons attest to the existence of considerable organisation within social groups. The procurement of metal supplies, the exploitation and propagation of metallurgical expertise, of weapon design and of combat skills all require a degree of long term planning and common purpose. The decision to organise and plan for regular combat, or the threat thereof, can both be a symptom and, ultimately, a reinforcement of social cohesion.

The weapons have provided an insight into the technical expertise of these people and the complexity of their society and beliefs. Weapons, their symbolism and the numerous different ceremonials in which they were involved clearly had their own place within the cosmology by which the people understood and lived within their universe. It is impossible to over-emphasise the total integration of this cosmology with what we would term 'secular' activities and how alien this modern western division into religious and secular aspects would be in almost all other societies and times. It is seen in agriculture, where numerous agricultural implements, particularly quern stones, are ceremonially deposited (Pryor 1998), and in the design of dwellings (Parker Pearson 1993), where entrances and certain activities are uniformly aligned relative to celestial phenomena, as well as in the deposition of weapons examined herein.

It must also be stressed how wide the people's horizons could be, Clearly to some, and, indeed, to an increasing number, long distance travel was no barrier; they exchanged goods and knowledge over distances which were daunting to most before modern transport removed the effort and dangers involved. The importance of this increasingly common external contact is not limited to the opportunities to acquire and exchange material goods, although this may have formed at least part of the motivation for the dominant siting of the early hill 'forts' and some at least of the ring 'forts'. The exchange of knowledge, ideas and traditions probably had much greater influence on the nature of society than any amount of bronze or fine textiles. The power structures within society appear not to have hindered the adoption of at least some new ideas; they may even have been encouraged.

It is quite probable that the manner in which authority functioned within society placed considerable reliance on the existence of trained warriors but the evidence, although tenuous, does not support a society ruled by warriors *per se*. There is a decided lack of evidence for the episodes of major conflict and destruction which would inevitably result from the untrammelled control of competing 'warrior chieftains' over society. The complexity of the rituals in which weapons featured, including the wholesale destruction of viable weapons, is also unlikely to arise from a wholly military authority. Areas, such as hill and ring 'forts', some of which, like Springfield, seem to have been directly connected with warrior groups and many of which seem to have seen ceremonial activities, were effectively delineated and 'separated' from areas of 'normal' settlement rather than being central to such areas. Overall the indicators point to the conclusion that society certainly sanctioned but, on the whole, controlled its warriors.

It is striking how, in so many aspects of life, there is a strong thread of continuity running through the prehistory of this island. Deposition of weapons, valuables and even human remains in rivers and wet places seems to have been a ceremonial understood, adapted and participated in by people from the Mesolithic through into the Christian era (Bradley 1990). Although people were constantly adapting familiar activities to incorporate and deal with new ideas and changing conditions, changes were rarely abrupt. Relationships with the land changed over time as did death rituals (Parker Pearson 1993, 125-34) but sites which were important in the rituals of people were often re-used and reinvested with ceremonial importance many centuries later, as the secondary burials at numerous Neolithic sites, such as Duggleby Howe, Yorkshire (Parker Pearson 1993, 48-9) and the deposition of a beautiful, deliberately destroyed, Iron Age chape at Flag Fen long after abandonment of the wooden platform (Pryor - pers. comm.), testify. Clearly it was not only the technical expertise of both farmers and artisans which was successfully passed down through the generations but also a sophisticated cosmology, which appears to have been sufficiently robust and flexible to allow people from different regions, whose means of sustenance varied widely, to communicate, co-operate and, when necessary, to fight, without destroying the coherence of society.

7.5 Weapons, Warfare and Society - Regional Differentiation within Britain

The existence of topographically different regions within Britain, whose climate, agriculture and material resources vary, when taken with the historical record of 'tribal' territories in later Iron Age Britain, the recognition of zones defined by typological differences in Late Bronze Age weaponry and the regional differences in quantity of bronze artefacts deposited indicated that particular attention should be paid to any regional variations shown up by the analyses undertaken.

The entire area was, for the purposes of this study, divided into four large regions, as shown in Figure 1.1.4. These were 'Scotland', which included North East England, 'East Anglia', which included the East Midlands, the 'South East', which included the upper Thames and the South coast and the 'West' , which covered all Western areas except in Scotland. This subdivision, broadly similar to that adopted by Colquhoun and Burgess (1988) in their regional study of Ewart Park swords, combines contiguous areas of similar topography along natural, navigable routes.

Although a high proportion of the weapons had received largely similar treatment after casting, the distribution of the characteristics relating to manufacturing methods, as shown in Chapters 2 and 4, showed some significant regional variations, indicating that, while the techniques used were widespread, their application differed according to the region where they were deposited, which, in most cases, is likely also to be the area in which they were made. The weapon makers would have passed on their knowledge and techniques within particular regions, probably through an 'apprenticeship' system, and the techniques used, which would necessarily have incorporated local preferences, appear to have been highly conservative throughout the period.

More weapons, especially swords, from the South East and East Anglia were heavily worked, and, in the South East, work hardened to an extent which might be deemed excessive, than elsewhere. South Eastern weapons were also found to be more likely to have undergone sufficient heat treatment to eliminate coring. The South East tended to have a higher proportion of good quality spearheads than other regions.

Regional variations shown in the edge fineness of swords, perhaps exaggerated by regional differences in preservation due to conditions of deposition, indicate that the choices made on the balance between edge sharpness and toughness also varied with Western weapons being less likely to favour sharpness. Western weapons deposited were also more likely to be incompletely annealed and tended to be less well cast than elsewhere, but were nonetheless quite adequate for combat use. This again may reflect regional traditions of smithing as well as the users' preferences.

The greater working of South Eastern and East Anglian weapons may indicate a greater emphasis on craftsmanship in those areas and, possibly, the existence of a greater number of highly skilled metal workers. The sometimes excessive hardening which resulted, especially in the South East was evidently not considered a major drawback indicating that appearance could be deemed more vital than utility in these areas. The adequate but less well finished weapons of the West could reflect a different set of values, with utility taking preference and fine finishing being deemed wasteful and, possibly, counter-productive rather than showing a simple lack of skill on the part of the local metal workers.

The compositional analyses, as detailed in Chapter 2.6, showed a very complex picture, with metal being recycled and mixed. Scottish weapons tended to show a low nickel level combined with a higher level of silver than of nickel and Western swords, together with a substantial proportion of the Blackmoor hoard from Hampshire, on the border of the Western region, showed virtually no silver content. Such results could have arisen as a result of the incorporation of copper or bronze of local origin, or possibly from an external area with which the region had uniquely strong links, into the 'pool' of bronze available for weapon production within the region

The most obvious regional variation for swords is the decided lack of Wilburton swords in the West and, especially, in the North despite the appearance of Wilburton types of spearheads in these regions. The wide range of dimensions of Scottish Ewart Park swords and the range of their trace element compositions and microstructural characteristics leads to the conclusion that this type probably covered a much longer time span in this area than elsewhere. Although the exposition of the links between typology and chronology was not a major aim of this work, these typological observations and analytical results provided circumstantial support for the theory that the Ewart Park type sword, in those areas where the Wilburton type did not appear, most notably in Scotland and the North, may well have appeared much earlier than is generally accepted.

Two high precision radiocarbon dates derived from spear shafts of the Waterden hoard, from Norfolk, were received after the initial submission of this work. The hoard consists of a variety of spearheads, not inconsistent with the Wilburton types, together with a large number of broken swords which, despite possessing some early features, are overwhelmingly of Ewart Park type. The dates produced, 2920+/-40BP and 2975+/-40BP (OxA-8761 and OxA-8762) coincide with those derived from the Wilburton hoard itself (Needham 1997) and calibrate to 1260-990BC and 1380-1040BC.

The presence of Ewart Park swords in a hoard of such early date in a territory, East Anglia, dominated at that time by Wilburton types indicates that the Ewart Park type not only was developed in the North, as acknowledged by Colquhoun and Burgess (1988) but that it was derived there more directly from Early sword types, as argued by Brown (1982), rather than from a much later 'simplification' of Wilburton material, as Colquhoun and Burgess (1988) conclude, although some influence from contemporary Wilburton material cannot be discounted.

Ewart Park sword characteristics seem to have first been merged with Wilburton characteristics in East Anglia, where the tendency of Ewart Park swords to show greater shoulder width is marked. Furthermore, although the typical Ewart Park sword does not appear to have been adopted in the South and East until after the demise of the Wilburton sword, it seems likely, during its early currency elsewhere, to have been regularly accompanied by spearheads which would be considered typical of the Wilburton tradition.

The regional variations in sword design did not seem related to major differences in the manner of their combat use and, therefore, must largely have reflected cultural preferences, including regional variations in the extent to which the weapons also functioned as prestige goods. The differences in edge damage seen therefore supplied the best information concerning the extent of combat use on a regional basis, though interpretation was complicated by the incidence of severe, deliberate damage, which was particularly prevalent in East Anglia.

The proportion of undamaged swords deposited in the South East was, at a third of the total, significantly high, while in Scotland and the West the proportions exhibiting damage compatible with combat use exceeded two thirds, compared with approximately one third in East Anglia and around half in the South East. Although we can have no information as to how the undeposited swords were used, these patterns are again compatible with rather more swords in the South East being treated as status goods, while those from the uplands were more slanted towards practical use. Spearheads were also particularly likely to be deposited damaged in Scotland and in the West, though the damage may be due more to deliberate breakage than combat.

The design of spearheads is, in some cases at least, more closely aligned with practical considerations than that of the swords. Among spearheads, the 'dumpy' type was almost entirely absent from upland regions, indicating that use of the thrown spear was probably not common there. Barbed blades were largely confined to the West, in the areas bordering the uplands, and the South East. Any use of these to attack and fire combustible material used in buildings or enclosures, as proposed herein, must therefore have been marked in these regions. The use of combustible materials for building would have been more common in lowland areas but the relative lack of such spearheads in East Anglia shows that this was not the only reason. East Anglia would have been a very wet region during the Late Bronze Age and thus relatively unsuitable for crop cultivation. This may have mitigated against the erection of the substantial buildings and grain storage facilities which are the likely targets for barbed spearheads.

Western plain lanceolate spearheads were likely to have relatively thick walls, which may, as with Western swords, show inferior manufacturing technique or a preference for robust weapons. Scottish ogival spearheads were considerably longer than those elsewhere, indicating that they served a slightly different function in this area. If these often decorated weapons were more commonly used for hunting than for combat, it is possible that the difference reflects a different, and larger, prey in the North.

Certain characteristics were over-represented in particular regions. These included blade openings and fillets, in Scotland and the West, and stepped edges and hollow casting, in East Anglia. Plain lanceolate and plain lanceolate hollow cast spearheads from East Anglia were inclined to be relatively short bladed and wide while the widest part of Scottish and Western blades tended to be closer to the tip. It is hard to see any practical reasons for these particular regional preferences, which must therefore be taken to show differences in cultural traditions and choices.

It is the pattern of interaction between pre-depositional treatments and depositional context of weapons which provides evidence not only for the superficial similarity in such practices across the country but also for the highly significant chronological, typological and regional differences in the frequencies and details thereof. Again, given the uncertain nature of the evidence, it was only the accumulation of large quantities of data which permitted analysis of these patterns.

South Eastern swords were more likely to be fragmentary than those from other regions, while South Eastern spearheads, unlike the swords, tended to be deposited complete but, as with swords, the split between wet and dry contexts was fairly even. This overall picture tends to obscure the more complex chronological pattern revealed due to the better representation in the South East of the less numerous sword types. Early South Eastern swords, as was the case with all regions, tended to be entire while the Wilburton swords, though incomplete, were substantial and the tendency to fragmentation was only marked in the Ewart Park swords. Most South Eastern swords, except for the broken and, especially, the fragmented Ewart Park swords, were deposited in wet contexts. Again the more fragmented weapons of all types tended to be found in 'dry' contexts. Basal-looped spearheads were almost all deposited in wet contexts while the later dumpy and ogival spearheads generally were not.

In East Anglia swords tended to be incomplete but were less inclined to fragmentation and many multiple piece swords were present. Those swords which were complete or had a large part present tended to be found in wet contexts, although the dry context of the large Waterden hoard reversed the tendency for those with multiple pieces present to be found in wet contexts. This pattern of breakage was apparent throughout the period although there was again a tendency for a higher proportion of Ewart Park swords to be present only as fragments. Spearheads in East Anglia, as elsewhere, tended more towards completeness than did the swords but, relative to other areas, the high proportion of almost complete spearheads stood out. The split between wet and 'dry' contexts was much more even for spearheads than swords but there was a preference for wet context deposition for near complete spearheads and for dry contexts for basal-looped, dumpy and more fragmentary spearheads.

Within Scotland chronological variation in depositional practices is indicated by the deposition of the one Early and two Wilburton type swords in pristine condition in wet contexts. A somewhat different picture was presented by the Ewart Park swords, of which the majority were entire but deposited in contexts which were not obviously wet. Scottish spearheads were even more slanted towards the 'non-wet' contexts. This was true in all typological groups adequately represented. The basal-looped, complex and ogival spearheads all tended to be entire or nearly so while among both plain and complex lanceolate spearheads the majority of fragmentary spearheads came from wet contexts.

The observed tendency of Western weapons to be deposited, broken, in wet contexts depends wholly on a few large hoards and was not the case for weapons deposited singly.

It is clear from the results of the project that there were regional differences in all matters relating to weaponry. The details of their manufacture reveal not only the extent of the skills required but sufficient differences in the regional applications thereof to deduce that skilled workers within each region passed their particular technical preferences down through the generations and, while there may be some suspicion that the most refined skills were less prevalent in the West, it is quite possible that this was simply a result of a regional preference for practicality.

Variations in design of the weapons deposited within particular regions may well in part have reflected topographical differences between regions which could have dictated differences in how weapons functioned; the lack of obvious 'throwing' spears in upland deposits may be an example. However, the reasons for which arms were produced depend on social and economic contexts, albeit that neither is unrelated to topography, and these evidently had considerable effect on the design and the use, both practical and symbolic, of weapons.

The extent to which weapons had clearly not been used in combat before deposition was high only in the South East, where it is possible that greater stress was laid on the prestigious nature of weapons and where riverine deposition is most obvious. The progression from deposition of complete weapons, through the deposition of deliberately destroyed weapons, to that of fragmentary weapons is also most marked in the South East. The progression to fragmentation is less prevalent in East Anglia, where the emphasis lay on rituals involving breaking of weapons into a few large pieces.

It would appear that, in these lowland areas, society's depositional treatment of weapons indicated a possible practical need to prevent the re-use of deposited weapons, alongside which ran a likely increase in deposition of small weapon fragments within collections of broken artefacts intended for recycling, whose value to society lay less in their symbolism of warfare, or individual histories, than in their bronze content. However, the overall impression given by the increasing elaboration of ritual destruction of weaponry is of a society experiencing an increasing fear of what the weaponry represented and a strong desire for cultural control over it.

Whether this cultural reaction shows a greater imposition of centralised control, as opposed to a consensus based on communally accepted values, together with a stronger accent on economic considerations, especially in the South East, than that elsewhere is open to question. However, the South East was clearly the area with the greatest range of external contact, where those who did not themselves travel widely would be most likely to have been in direct contact with those from different cultural communities. Against such a background it is possible that the warriors were a decided minority, seen by the majority rather more as an unpleasant necessity than as local hero and that warfare was seen as a disruption to more worthwhile pursuits rather than as an opportunity to increase the community's wealth, prestige or good standing with the gods. East Anglia, being intermediate between the South East and the North, and having good access for waterborne transport via both coast and rivers, may have seen rather more actual combat than the South East, leading to an understandable emphasis on destruction rituals.

The ambivalent attitude to weapons and warfare is less obvious in Scotland and the North, where, although spectacular depositions of ritually destroyed weapons did take place, most weapons were obviously used before deposition but were more likely to be buried entire, in quantities more commensurate with being the property of a single owner or family. Some elements of this type of 'personal weapon hoard' deposition may reflect cultural affinities with Scandinavia, where such deposition was prevalent at the time (Levy 1982). They seem to show that the local attitudes towards weapons and warfare were more relaxed and less ritually hidebound than in the South East and that, for some at least, weapons were intrinsic to their personal identity and that this was respected by the community as a whole.

The evidence from the West is much less clear, in that it is mostly a lack of evidence. However, it seems that here too combat was a natural part of life, where weapons were practical tools and were not ritually destroyed and discarded in large quantities. It is on the borders of this region that most weapon related activity is evident and where travel to and from the uplands would have crossed between the rivers and the mountain tracks. It is possible that control of these points, where storage of goods in transit would have featured, led to some of the need for warriors.

The perceived regional differences within Britain do, indeed, extend into the realm of weapons and warfare. The evidence has indicated that, in addition to the clear regional variations in weapon design and quantities deposited, there were differences in the manufacture, use and ritual decommissioning of the weapons. Moreover, many of these differences do point to a subtly different cultural attitude towards warriors and warfare, dependent on the region concerned, its topography, economy, traditions and, to some extent, the influence of its external contacts.

7.6 Further Work

The subjects considered within this study, although limited to aspects of life directly related to the weapons examined, have encompassed a very wide range of topics. Limitations of time and practical considerations mean that it is necessary to conclude this particular project but this in no way should be taken to indicate that the author feels that the subject matter has been exhaustively investigated as this is very far from the case. There is an ample and increasing supply of further evidence to interpret.

There are some obvious areas for future work within the field of Bronze Age weaponry. This study could not attempt to provide a comprehensive catalogue of British spearheads and such a volume is needed. Although the dimensions measured for this study did throw some light on variations within the basic lanceolate spearhead category it may be that smaller details, in particular edge bevel width, precise peghole position and detail of socket shape will prove significant. An extension of the high precision radiocarbon dating programme to incorporate more dates from shafts of 'plain' spearheads and of spearheads and other artefacts from particular regions, such as that underway in Scotland (Cowie - pers. comm.), would be most valuable. There is also clearly further experimental work to be done, both in making and in using weapons, and here again it is the spearheads which are most obviously in need.

It is perhaps less likely that future excavations and chance finds will produce direct evidence of physical contexts related to weapons and warfare, rather than to weapon deposition *per se*. Indeed the circumstances of weapon deposition in the later Bronze Age appear largely to conspire against their physical context being directly related to other aspects of life.

The greatest difficulty encountered in the course of this study must be the lack of physical contextual detail, even of deposition, for the vast majority of the artefacts examined. Had the detail expected from a modern excavation been available for all the weapons examined it would probably have been impossible to incorporate it all within this particular research framework but the lack of it is still a major shortcoming. Each weapon deposition should be interpreted as an event in itself and attention paid to the precise circumstances surrounding it before parallels are drawn with other similar events. This is not to say that it is impossible to compare and contrast such episodes across time and space, as has been attempted herein, but such comparisons must be more meaningful when contextual detail can be incorporated.

An inevitable result of the huge increase in pre-development excavations and 'watching briefs', underlined by papers given at a recent conference, 'Place and Space in the British Bronze Age' (Cambridge, April 1999), some of which were referred to in Chapter 6 above, is an enormous amount of new evidence relating to every aspect of life in the Late Bronze Age. There are detailed investigations of sites related to the exploitation of specialised environments, such as wetlands, estuaries and mining sites, while the numbers and variety of settlement and 'special' riverside sites found have grown apace.

The contextual information concerned is of very high quality and evidence for structured deposition on many sites of differing types, such as Runnymede (Needham & Sorensen 1988) and Flag Fen (Pryor 1991, 1992, 1998), is increasingly encompassing more 'humble' sites such as at Gadebridge, Herts, where 'excavation of an enclosed settlement produced single cremations in association with roundhouses and other structures, as well as a cluster of features with human remains' and at 'Thorley, on the Herts/Essex border where an area of roundhouses was bounded by a ditched enclosure with entrances marked by pits containing selected pottery fragments and where human remains were associated with ancillary structures' (J Last, paper given at 'Place and Space in the British Bronze Age', Cambridge April 1999).

Other areas of study are less likely to benefit from developer funding and require planned academic investigation. This is already underway in the field of early mining and the results should shed more light on the extent to which the mineral resources of Britain were exploited during the Bronze Age. They may provide some further information, via the study of the artefacts from the immediate vicinity, as to whether or not local metal resources were exploited in manufacture, as suggested by Rohl (1995), but it is clear that there will be no easy answers. The subject of waterborne transport is one which leaves plenty of room for further investigation, by underwater exploration of areas likely to have preserved remains, by experimental work, such as the boat reconstruction project recently reported (Clark 1997) and by experimental use of the products of such projects.

It should be possible to build up, from modern excavations and related studies, an approach to artefact studies which includes and uses these detailed physical contexts and enables them to take their place within the more comprehensive interpretations which this fresh evidence should encourage. There is scope for local and regional studies to be built up in such a manner that the 'big picture', in all its variety, will emerge.

This study has used resources, the museum collections, which are currently available and from which detailed information may be extracted, to produce a 'sketch' of that 'big picture', which may well be of use in guiding the emphases of investigations in the future. The collection of sufficient data to permit statistical analysis led to a regional division which was rather coarser than strictly desirable and, despite this, meant that finer subdivision of the data within areas was problematic. This was particularly so in the West of the country, where the sparseness of weapon deposits is exacerbated by the relative dispersion, to various collections, and, in some cases, probable loss of those which have been discovered, when compared with other regions. The late establishment of the collection of the National Museum of Wales, at the turn of the century and therefore some fifty years later than the other major regional and national collections, meaning that there was no natural 'home' in this area for collections made in the 18th and 19th centuries when the antiquaries in question died, has probably contributed to this difficulty. As a result many more detailed questions regarding seeming regional differences were impossible to answer statistically and only further examination of weapons from those under-represented areas will rectify this.

There is also the question of bias in the data collected and the extent to which this may slant the findings. Thanks to the generosity of the museums concerned the samples taken here were not nearly so biased towards incomplete and heavily damaged swords as had been expected. The bias towards less damaged weapons within the major museum collections cannot be quantified but must, intuitively, exist. It is especially likely that single finds of fragmentary weapons were rarely preserved or recorded until relatively recently and, in these days of mechanised agriculture, many may still be escaping notice. Awareness of the bias inherent in the populations of artefacts collected is necessary from the planning of the study through to the interpretation of the results. It is rare that the luxury of a truly random statistical sample is available.

The lack of homogeneity of ancient bronze remains a considerable hurdle to metallurgical analysis. When allied to small sample size, it makes the interpretation of metallographic and compositional results less than simple. However, the use of large numbers of samples has been shown here to mitigate such problems of interpretation. Similar investigations of other artefact categories, such as wood working tools, agricultural implements and personal ornaments could well yield equally valuable information.

There is no doubt that the ancient metal workers possessed expertise in working bronze which is almost entirely lost to modern practitioners and it was only the patience, inventiveness, skill and sheer hard work of Robert (Helgi) Seaton, detailed in Chapter 3, which enabled the experimental part of the project to achieve its goals. It is hoped that the experience gained during this practical work may be of some benefit to others in the future although no amount of instruction is a substitute for practice when attempting to emulate the achievements of the bronze workers of prehistory.

The challenge of integrating and interpreting the excavational, artefactual and experimental information into a coherent whole remains daunting and clearly demands that a great deal of material be made more accessible and that artefacts held in public collections be investigated thoroughly. However, there is also a great need to ensure that chance finds of any artefacts have as much recording and investigation of physical context as possible. This will involve educating the public in general, and metal detectorists in particular, to appreciate that it is not merely the artefacts which are important.

The public do seem to appreciate one facet which is often in danger of becoming lost among the finer points of archaeological investigation; it is the people who produced the material we study who are fundamental to all that we do. The habit of treating artefact studies simply as exercises in technological or chronological detection must be broken if they are to be used to their full potential. The artefacts can tell so much more of the stories of the people who made, used, touched and saw them.

Bibliography

Agricola G (translated Hoover & Hoover) 1950. *De Re Metallica*. New York. Dover Publications Inc.

Alcock L 1972. *'By South Cadbury is that Camelot ...' - The Excavation of Cadbury Castle 1966-1970*. London. Thames & Hudson.

Allen I M, Britton D and Coghlan H H 1970. *Metallurgical reports on British and Irish Bronze Age Implements and Weapons in the Pitt Rivers Museum*. Oxford. Pitt Rivers Museum Occasional Papers on Technology, 10.

Askew G P, Payton R W and Shiel R S 1985. Upland Soils and Land Clearance during the Second Millennium BC, in D Spratt and C Burgess (ed) *Upland Settlement in Britain: The Second Millennium BC and after*. Oxford. British Archaeological Reports 143, 5-34.

Avery M 1976. Hillforts of the British Isles: A Student's Introduction, in D W Harding (ed) *Hillforts - Later Prehistoric Earthworks in Britain and Ireland*. London. Academic Press, 1-58.

Avery M 1993. *Hillfort Defences of Southern Britain*. Oxford. British Archaeological Report 231.

Bailey A R 1960. *A Text Book of Metallurgy*. London. MacMillan.

Baillie M G L and Brown D M 1991. A Dendro-date from Haughey's Fort. *Emmania (Bulletin of the Navan research Group)* 8.

Balee W 1984. The Ecology of Ancient Tupi Warfare, in R B Ferguson (ed). *Warfare Culture and Environment*. Orlando, Florida. Academic Press, 241-265.

Barclay A and Cromarty A 1999. The Bronze Age of the Oxford region: settlement and sequence, unpublished paper given at an open forum 'Place and Space in the British Bronze Age', Cambridge 24-25 April 1999.

Bardon J 1992. *A History of Ulster*. Belfast. Blackstaff Press.

Barrett C S and Massalski T 1966 (3rd edition). *Structure of Metals*. New York. McGraw Hill.

Barrett J C 1976. Deverel-Rimbury: Problems of Chronology and Interpretation, in C B Burgess and R Miket (ed) *Settlement and Economy in the third and second millennia BC*. Oxford. British Archaeological Report, British Series 33, 289-307.

Barrett J C 1980. The Pottery of the Later Bronze Age in Lowland England. *Proceedings of the Prehistoric Society* 46, 297-319.

Barrett J C 1980. The Evolution of Later Bronze Age Settlement, in J C Barrett and R Bradley (ed) *The British Later Bronze Age*. Oxford. British Archaeological Report 83(i), 77-95.

Barrett J C 1989. Food, Gender and Metal: Questions of Social Reproduction, in M L S Sorensen and R Thomas (ed) *The Bronze Age-Iron Age Transition in Europe*. Oxford. British Archaeological Report, International Series 483, 305-20.

Barrett J C 1994. *Fragments from Antiquity*. Oxford. Blackwell.

Barrett J C and Bradley R 1980. The Later Bronze Age in the Thames Valley, in J C Barrett and R Bradley (ed) *The British Later Bronze Age*. Oxford. British Archaeological Report 83(i), 247-269.

Barrett J C and Needham S P 1988. Production, Circulation and Exchange: Problems in the Interpretation of Bronze Age Bronzework, in J C Barrett and I A Hinnes (ed) *The Archaeology of Context in the Neolithic and Bronze Age - Recent Trends*. Sheffield. Sheffield University, Dept. of Archaeology & Prehistory, 127-40.

Barrett J C, Bradley R & Green M 1991. *Landscape, Monuments and Society. The Prehistory of Cranbourne Chase.* Cambridge. Cambridge University Press.

Barth F 1959. *Political Leadership among Swat Pathans.* L.S.E. Monographs on Social Anthropology No 19. London. The Athlone Press.

Biolsi T 1984. Ecological and Cultural Factors in Plains Indian Warfare, in R B Ferguson (ed). *Warfare Culture and Environment.* Orlando, Florida. Academic Press, 141-68.

Bohannon P (ed) 1967. *Law and Warfare*. New York. The Natural History Press.

Boyle A and Brossler A 1999. Reading Business Park: the results of phases 1 and 2, unpublished paper given at an open forum 'Place and Space in the British Bronze Age', Cambridge 24-25 April 1999.

Bradley R 1984. *The social foundations of prehistoric Britain*. London. Longman.

Bradley R 1988. Hoarding, recycling and the consumption of prehistoric metalwork: technological change in western Europe. *World Archaeology* 20 #2, 249-260.

Bradley R 1990. *The Passage of Arms*. Cambridge. Cambridge University Press.

Bradley R 1993. Archaeology: the loss of nerve, in N Yoffee and A Sherratt (ed) *Archaeological Theory; who sets the agenda?* Cambridge. Cambridge University Press.

Bradley R amd Edmonds M 1993. *Interpreting the axe trade: production and exchange in Neolithic Britain.* Cambridge. Cambridge University Press.

Bradley R and Ellison A 1975. *Rams Hill*. Oxford. British Archaeological Report 19.

Briard J 1965. *Les depots Bretons et l'Age du Bronze Atlantique*. Rennes.

Briard J 1976. *The Bronze Age in Barbarian Europe*. London. Book Club Associates.

Briard J 1988. La Metallurgie du Groupe Saint-Brieuc-des-Iffs, in *Actes du Colloque de Nemours 1986.* Memoires du Musee de Prehistoire d'Ile-de-France 1, 533-8.

Briard J 1993. Relations between Armorica and Great Britain during the Bronze Age, in C Scarre and F Healy (ed) *Trade and Exchange in Prehistoric Europe*. Oxford. Oxbow, 183-90.

Bridgford S D 1997. Mightier than the pen? an edgewise look at Irish Bronze Age swords, in J Carman (ed) *Material Harm - archaeological studies of war and violence*. Glasgow. Cruithne Press, 95-115.

Bridgford S D 1997b. The first weapons designed only for war. *British Archaeology* 22, 7.

Bridgford S D 1998. British Late Bronze Age swords - the metallographic evidence, in C Mordant, M Pemot and V Rychner (ed) *L'atelier du bronzier en Europe du XX^{e} au VIII^{e} siecle avant notre ere* 2. Paris. CTHS, 205-218.

Briggs C S 1983. Copper Mining at Mount Gabriel, Co Cork: Bronze Age Bonanza or Post-Famine Fiasco? *Proceedings of the Prehistoric Society* 49, 317-33.

Briggs C S 1991. Some Processes and Problems in Later Prehistoric Wales and Beyond, in Chevillot and Coffyn (ed) *Le Bronze Atlantique, 1er Colloque de Beynac*: 10-14 Sept.1990, 59-76.

Britton D 1961. A Study of the Composition of Wessex Culture Bronzes. *Archaeometry* 4, 39-52.

Britton D 1963. Traditions of Metal Working in the Later Neolithic and Early Bronze Age of Britain. *Proceedings of the Prehistoric Society* XXIX, 258-325,

Brown M A and Blin-Stoyle A E 1959. A Sample Analysis of British Middle and late Bronze Age Material using Optical Spectrometry. *Proceedings of the Prehistoric Society* XXV, 188-208.

Brown M A 1982. Swords and Sequence in the British Bronze Age. *Archaeologia* CVII, 1-41.

Brown N 1999. Springfield Lyons in its landscape context, paper given at an open forum 'Place and Space in the British Bronze Age', Cambridge 24-25 April 1999.

Bruck J 1995. A place for the dead: the role of human remains in Late Bronze Age Britain. *Proceedings of the Prehistoric Society* 61, 245-278.

Brun P 1991. le Bronze Atlantique et ses Subdivisions Culturelles: Essai de Definition, in Chevillot and Coffyn (ed) *Le Bronze Atlantique, 1er Colloque de Beynac*: 10-14 Sept.1990, 11-24.

Brun P 1993. East-West Relations in the Paris Basin during the Late Bronze Age, in C Scarre and F Healy (ed) *Trade and Exchange in Prehistoric Europe*. Oxford. Oxbow, 171-82.

Buckley D G and Hedges J D 1987. *The Late Bronze Age and Saxon settlements at Springfield Lyons, Essex*. Essex County Council Occasional Paper No 5.

Budd P, Pollard A M, Scaife B and Thomas R G 1995. The possible fractionation of lead isotopes in ancient metallurgical processes. *Archaeometry* 37, 1, 143-150.

Burgess C B 1968a. *Bronze Age Metalwork in Northern England*. Newcastle-upon-Tyne. Oriel Press.

Burgess C B 1968b. The Later Bronze Age in the British Isles and North-Western France. *The Archaeological Journal* CXXV, 11-45.

Burgess C B 1974. The Bronze Age, in C. Renfrew (ed) *British Prehistory: A new outline*. London. Duckworth, 165-233.

Burgess C B 1979. A Find from Boyton Suffolk and the End of the Bronze Age in Britain and Ireland, in C B Burgess and D G Coombs (ed) *Bronze Age Hoards; some finds old and new*. Oxford. British Archaeological Report 67, 269-283.

Burgess C B 1985. Population Climate and Upland Settlement, in D Spratt and C Burgess (ed) *Upland Settlement in Britain: The Second Millennium BC and after*. Oxford. British Archaeological Reports 143, 195-230.

Burgess C B 1988. Britain at the Time of the Rhine-Swiss Group, in P Brun and C Mordant (ed) *Le groupe Rhin-Suisse France orientale et la notion de civilisation des Champs d'Urnes*. Memoires du Musee de Prehistoire d'Ile-de-France No 1, 559-573.

Burgess C B 1989. Volcanoes, catastrophe and the Global Crisis of the late second Millennium BC. *Current Archaeology* 117, 325-329.

Burgess C B 1991. The East and the West: Mediterranean Influence in the Atlantic World in the Later Bronze Age, c. 1500-700BC, in Chevillot and Coffyn (ed) *Le Bronze Atlantique, 1er Colloque de Beynac*: 10-14 Sept.1990, 25-45.

Burgess C B, Coombs D G and Davies D G 1972. The Broadward Complex and Barbed Spearheads, in F Lynch and C Burgess (ed) *Prehistoric Man in Wales and the West - essays in honour of Lily F. Chitty*. Bath. Adams & Dart.

Campbell J 1991. *Castings*. Oxford. Butterworth-Heinemann.

Carman J 1997 Approaches to violence, in J Carman (ed) *Material Harm - archaeological studies of war and violence*. Glasgow. Cruithne Press, 1-24.

Cameiro R L 1990. Chiefdom-level warfare as exemplified in Fiji and the Cauca Valley, in J Haas (ed). *The Anthropology of War*. Cambridge. Cambridge University Press, 190-211.

Chagnon N A 1977 (1st ed 1968). *Yanomamo*. Holt, Rinehart & Winston. New York.

Chagnon N A 1990. Reproductive and somatic conflicts of interest in the genesis of violence and warfare among tribesmen, in J Haas (ed). *The Anthropology of War*. Cambridge. Cambridge University Press, 77-104.

Champion T 1982. Fortification, ranking and subsistence, in C Renfrew and S Shennan (ed) *Ranking Resource and Exchange - aspects of the archaeology of early European society*. Cambridge. Cambridge University Press, 61-6.

Champion T, Gamble C, Shennan S and Whittle A 1984. *Prehistoric Europe*. London. Academic Press.

Charles J A 1973. Heterogeneity in metals, *Archaeometry* 15, 105-114.

Charles J A 1975. Where is the tin? *Antiquity* XLIX, 19-24.

Chase W T 1972. Comparative Analysis of Archaeological Materials - Bronzes - Interim Report #2. *International Committee on Metals Conference*, Madrid.

Childe V G 1948. The Final Bronze Age in the Near East and in Temperate Europe. *Proceedings of the Prehistoric Society* XIV, 177-195.

Chippindale C 1993. Ambition, deference, discrepancy, consumption: the intellectual background to a post-processual archaeology, in N Yoffee and A Sherratt (ed) *Archaeological Theory; who sets the agenda?* Cambridge. Cambridge University Press.

Clark P 1997. Lessons from Bronze Age boat-building. *British Archaeology* 24, 7.

Clough T H McK 1979. Bronze Age metalwork from Rutland, in C Burgess and D G Coombs (ed) *Bronze Age Hoards: some finds old and new*. Oxford. British Archaeological Reports 67, 117-35.

Coggins D 1983. *A Hoard of Late Bronze Age Metalwork from Gilmonby, near Bowes, Co Durham*. The Bowes Museum archaeological reports 2.

Coghlan H H 1960. Prehistorical Working of Bronze and Arsenical Copper. *Sibrium* 5, 145-52.

Coghlan H H 1970a. *British and Irish Bronze Age Implements in the Borough of Newbury Museum*. Newbury. The Borough of Newbury Museum.

Coghlan H H 1970b. *A Report upon the Hoard of Bronze Age tools and Weapons from Yattendon, Near Newbury, Berkshire*. Newbury. The Borough of Newbury Museum.

Coghlan H H 1975. *Notes on the Prehistoric Metallurgy of Copper and Bronze in the Old World*. Occasional Papers on Technology, 4, second edition. Oxford. Oxford University Press.

Coghlan H H and Case H 1957. Early Metallurgy of Copper in Ireland and Britain. *Proceedings of the Prehistoric Society* XXIII, 91-123

Coghlan H H and Raftery J 1961. Irish Prehistoric Casting Moulds. *Sibrium* 6.

Coghlan H H and Parker G 1969. Metallographic Research as a Museum Aid - An Examination of Two Pure Copper Flat Axes. Newbury. The Borough of Newbury Museum.

Cohen R 1984. Warfare and State Formation: Wars Make States and States Make Wars, in R B Ferguson (ed). *Warfare Culture and Environment*. Orlando, Florida. Academic Press, 329-358.

Coles J M 1960. Scottish Late Bronze Age Metalwork. *Proceedings of the Society of Antiquaries of Scotland* 93, 16-134.

Coles J M 1962. European Bronze Age Shields. *Proceedings of the Prehistoric Society* XXVIII, 156-190.

Coles J M 1972. Later Bronze Age Activity in the Somerset Levels. *The Antiquaries Journal LII, Part II*, 269-275.

Coles J and Coles B 1986. *Sweet Track to Glastonbury. The Somerset Levels in Prehistory*. London. Thames & Hudson.

Coles J M and Harding A F 1979. *The Bronze Age in Europe*. London. Methuen.

Collins A E P 1970. Bronze Age Moulds in Ulster. *Ulster Journal of Archaeology* 33.

Collis J 1982. Gradual growth and sudden change - urbanisation in temperate Europe, in C Renfrew and S Shennan (ed) *Ranking Resource and Exchange - aspects of the archaeology of early European society*. Cambridge. Cambridge University Press, 73-8.

Colquhoun I. 1979. The Late Bronze Age Hoard from Blackmoor, Hampshire, in C Burgess and D G Coombs (ed) *Bronze Age Hoards; some finds old and new*. Oxford. British Archaeological Report 67, 99-116.

Colquhoun I and Burgess C 1988. *The Swords of Britain*. Prahistorische Bronzefunde IV, 5. Munich. Beck.

Coombs D G 1975a. Bronze Age weapon hoards in Britain. *Archaeologia Atlantica* 1, 49-81.

Coombs D G 1975b. The Dover harbour bronze find - a Bronze Age wreck? *Archaeologia Atlantica* 1, 49-81.

Coombs D G 1979a. A Late Bronze Age hoard from Cassiobridge Farm, Watford, Hertfordshire, in C Burgess and D G Coombs (ed) *Bronze Age Hoards: some finds old and new*. Oxford. British Archaeological Reports 67, 197-234.

Coombs D G 1979b. The Figheldean Hoard, Wiltshire, in C Burgess and D G Coombs (ed) *Bronze Age Hoards: some finds old and new.* Oxford. British Archaeological Reports 67, 253-68.

Coombs D G 1988. The Wilburton Complex and Bronze Final II in Atlantic Europe, in P Brun and C Mordant (ed) *Le groupe Rhin-Suisse France orientale et la notion de civilisation des Champs d'Urnes.* Memoires du Musee de Prehistoire d'Ile-de-France No 1, 575-581.

Coombs D G 1991. Bronze Objects, in C R Musson, *The Breiddin Hillfort: A later prehistoric settlement in the Welsh Marches.* London. Council for British Archaeology Research Report 76, 132-9.

Coombs D G 1992. Metalwork from Fengate and Flag Fen. *Antiquity* 66, 251, 504-517.

Coombs D G and Bradshaw J 1979. A Carp's Tongue hoard from Stourmouth, Kent, in C Burgess and D G Coombs (ed) *Bronze Age Hoards: some finds old and new.* Oxford. British Archaeological Reports 67, 151-96.

Cowen J D 1951. The Earliest Bronze Swords in Britain and their Origins on the Continent of Europe. *Proceedings of the Prehistoric Society* XVII, 195-213.

Cowen J D 1967. The Hallstatt Sword of Bronze: on the Continent and in Britain. *Proceedings of the Prehistoric Society* XXXIII, 377-454.

Cowie T 1994. A Bronze Age Gold Torc from the Minch. *Hebridean Naturalist* 12, 19-21.

Cowie T, O'Connor B and Proudfoot E 1991. A Late Bronze Age Hoard from St Andrews, Fife, Scotland: a preliminary report, in Chevillot and Coffyn (ed) *Le Bronze Atlantique, 1er Colloque de Beynac*: 10-14 Sept.1990, 49-58.

Cowie T, Hall M. O'Connor B and Tipping R 1996. The Late Bronze Age hoard from Corrymuckloch, near Amulree, Perthshire: an interim report. Tayside and Fife Archaeological Journal, vol 2, 60-9.

Cowie T, Northover J P and O'Connor B 1998. The St Andrews, Fife, hoard: context and chronology in the Scottish Late Bronze Age, in C Mordant, M Pernot and V Rychner (ed) *L'atelier du bronzier en Europe du XXe au VIIIe siecle avant notre ere 3.* Paris. CTHS, 45-58.

Craddock P T 1980. The Composition of the Copper Alloys, in F Pryor, *A Catalogue of British and Irish Prehistoric Bronzes in the Royal Ontario Museum.* Toronto. Royal Ontario Museum, 67-76.

Craddock P T 1986. Bronze Age Metallurgy in Britain. Current Archaeology 99, 106-109.

Craddock P T 1990. Copper Smelting in Bronze Age Britain: Problems and Possibilities, in P Crew and S Crew S (ed) *Early Mining in the British Isles.* Plas Tan y Bwlch, Snowdonia National Park Study Centre, Occasional Paper No 1, 69-71.

Craddock P T 1992a. Copper Production in the Bronze Age of the British Isles. *Bulletin of the Metals Museum* 18. Japan Institute of Metals, 3-28.

Craddock P T 1992b. Problems and potentials in sourcing metals in prehistoric Europe, in C Scarre and F Healy (ed) *Trade and Exchange in Prehistoric Europe.* Oxford. Oxbow.

Craddock P T 1994. Recent progress in the study of early mining and metallurgy in the British Isles. *Historical Metallurgy*, Volume 28 Number 2.

Craddock P T, Leese M, Matthews K and Needham S P 1990. The Metallurgy of the Petters Bronzes. The composition of the metalwork, in S P Needham *The Petters Late Bronze Age Metalwork*. London. British Museum Occasional Paper no 70, 77-88.

Crew P and Crew S (ed) 1990. *Early Mining in the British Isles*. Plas Tan y Bwlch, Snowdonia National Park Study Centre, Occasional Paper No 1.

Cummins W A !974. The Neolithic Stone Axe Trade in Britain. *Antiquity* 68, 201-5.

Cunliffe B and O'Connor B 1979. The Late Bronze Age hoard from Danebury Hants, in C Burgess and D G Coombs (ed) *Bronze Age Hoards; some finds old and new*. Oxford. British Archaeological Report 67, 235-44.

Darvill T 1987. *Prehistoric Britain*. London. Batsford.

Davies D G 1979. Hatfield Broad Oak, Leigh, Rayne, Southchurch: Late Bronze Age hoards from Essex, in C Burgess and D G Coombs (ed) *Bronze Age Hoards: some finds old and new*. Oxford. British Archaeological Reports 67, 149-72.

Denison S 1997. Sussex 'Flag Fen' decays without record. *British Archaeology* 24, 5.

Drewett P 1982. Later Bronze Age downland economy and excavations at Black Patch, East Sussex. *Proceedings of the Prehistoric Society* 48, 321-400.

Dutton L A.1990. Surface Remains of Early Mining on the Great Orme, in P Crew and S Crew S (ed) *Early Mining in the British Isles*. Plas Tan y Bwlch, Snowdonia National Park Study Centre, Occasional Paper No 1, 11-15.

Ehrenberg M R 1977. *Bronze Age Spearheads from Berks, Bucks and Oxon*. Oxford. British Archaeological Report 34.

Ellis P 1993. *Beeston Castle , Cheshire - a report on the excavations 1968-85 by Laurence Keen and Peter Hough*. London. English Heritage.

Ellison A 1982. Towards a socio-economic model for the Middle Bronze Age in southern England, in I Hodder, G Isaac and N Hammond (ed) *Pattern of the Past: Studies in Honour of David Clarke*. Cambridge University Press. Cambridge, 413-35.

Eogan G 1964. The Later Bronze Age in Ireland in the light of recent research. *Proceedings of the Prehistoric Society* XXX.

Eogan G 1965. *Catalogue of Irish Bronze Swords*. Dublin. National Museum of Ireland.

Eogan G. 1983 *The Hoards of the Irish Later Bronze Age*. Dublin. University College Dublin.

Evans J 1881. *The Ancient Bronze Implements, Weapons and Ornaments of Great Britain and Ireland*. London. Longmans, Green & Co.

Evans J 1884. 'On a hoard of bronze objects found in Wilburton Fen, near Ely. *Archaeologia* 48, 106-14.

Evans-Pritchard E E 1940. *The Nuer*. Oxford. Clarendon Press.

Evans-Pritchard E E 1971. *The Azande*. Oxford. Clarendon Press.

Ewers J C 1967. Blackfoot Raiding for Horses and Scalps, in P Bohannon (ed) *Law and Warfare*. New York. Natural History Press, 327-344.

Farley M 1979a. A Carp's Tongue hoard from Aylesbury Buckinghamshire, in C Burgess and D G Coombs (ed) *Bronze Age Hoards; some finds old and new*. Oxford. British Archaeological Report 67, 137-44.

Farley M 1979b. A small Late Bronze Age hoard from Ellesborough, Buckinghamshire, in C Burgess and D G Coombs (ed) *Bronze Age Hoards; some finds old and new*. Oxford. British Archaeological Report 67, 145-8.

Fasnacht W 1998. Evolution de la techniquede fonte du cuivre et du bronze - reconstitution experimentale, in C Mordant, M Pemot and V Rychner (ed) *L'atelier du bronzier en Europe du XX^e au VIII^e siecle avant notre ere 2*. Paris. CTHS, 101-6.

Ferguson R B (ed) 1984. *Warfare Culture and Environment*. Orlando, Florida. Academic Press.

Ferguson R B. 1984 Studying War, in R B Ferguson (ed). *Warfare Culture and Environment*. Orlando, Florida. Academic Press, 1-82.

Ferguson R B 1984. A Reexamination of the Causes of Northwest Coast Warfare, in R B Ferguson (ed). *Warfare Culture and Environment*. Orlando, Florida. Academic Press, 267-328.

Ferguson R B 1990. Explaining War, in J Haas (ed). *The Anthropology of War*. Cambridge. Cambridge University Press, 26-61.

Ferguson R B and Whitehead N L (ed) 1992. *War in the Tribal Zone*. Santa Fe, New Mexico. School of America Research Press.

Ferguson R B and Whitehead N L 1992. The Violent Edge of Empire, in R B.Ferguson and N L Whitehead (ed) *War in the Tribal Zone*. Santa Fe, New Mexico. School of America Research Press, 1-30.

Fitzpatrick A C, Ellis C and Allen M J 1996. Bronze Age 'Jetties' or Causeways at Testwood Lakes, Hampshire, Great Britain. *Past* 24, 9-10.

Fleming A 1982. Social boundaries and land boundaries, in C Renfrew and S Shennan (ed) *Ranking Resource and Exchange - aspects of the archaeology of early European society*. Cambridge. Cambridge University Press, 52-6.

Flemimg A 1985. Upland settlement in Britain: the second millennium BC and after, in D Spratt and C Burgess (ed) *Upland Settlement in Britain: The Second Millennium BC and after*. Oxford. British Archaeological Reports 143, 377-83.

Fleming A 1991. *The Dartmoor Reaves*. London, Batsford.

Forbes R J 1950. *Metallurgy in Antiquity*. Leiden. E.J. Brill.

French C A I 1992. Fengate to Flag Fen: soil and sediment. *Antiquity* 66, 251, 458-461.

Gale D 1990. Prehistoric Stone Mining Tools from Alderley Edge, in P Crew and S Crew S (ed) *Early Mining in the British Isles*. Plas Tan y Bwlch, Snowdonia National Park Study Centre, Occasional Paper No 1, 47-8.

Gale N H and Stos-Gale Z A 1982. Bronze Age copper sources in the Mediterranean: A new approach. *Science* 216, 11-20.

Gibson T 1990. Raiding trading and tribal autonomy in insular Southeast Asia, in J Haas (ed). *The Anthropology of War*. Cambridge. Cambridge University Press, 125-45.

Gimbutas M 1965. *Bronze Age Cultures of Central and Eastern Europe*. The Hague. Mouton.

Gingell C 1979. The Bronze and Iron Hoard from Melksham and another Wiltshire Find, in C Burgess and D G Coombs (ed) *Bronze Age Hoards; some finds old and new*. Oxford. British Archaeological Report 67, 245-51.

Goldberg N J and Findlow F J 1984. A Quantitative Analysis of Roman Military Operations in Britain, circa AD 43 to 238, in R B Ferguson (ed). *Warfare Culture and Environment*. Orlando, Florida. Academic Press, 359-385.

Gomez de Soto J 1981. Nouvelles considerations sur l'epee du Bronze final de Forge d'Aunis (Charente Maritime). *Bulletin de la Societe Prehistorique Francaise* 78/4, 123-8.

Gomez de Soto J 1987. Les Epees du Cognacais (Charente) et la Chronologie des Epees du Type de Chelsea-Ballintober en France. Actes du Colloque de Bronze de Lille-R.A.P./S.P.F

Gomez de Soto J. 1991. Le fondeur, le trafiquant et les cuisiniers: la broche d'Amathone de Chypre et la chronologie absolue du Bronze Final Atlantique, in Chevillot and Coffyn (ed) *Le Bronze Atlantique, 1er Colloque de Beynac*: 10-14 Sept.1990, 369-373.

Gomez de Soto J 1993. Cooking for the Elite: Feasting Equipment in the Late Bronze Age, in C Scarre and F Healy (ed) *Trade and Exchange in Prehistoric Europe*. Oxford. Oxbow, 191-7.

Gomez de Soto J 1994. Une Bouterolle a Section Losangique du Bronze Final en Centre-Ouest. *Bulletin de la Societe Prehistorique Francaise* 91/3, 198-9.

Gomez de Soto J and Pautreau J P 1988. Le Crochet Protohistorique en Bronze de Thorigne a Coulon (Deux-Sevres). *Archaologisches Korrespondenzblatt* 18, 31-42.

Gregor T 1990. Uneasy peace: intertribal relations in Brazil's Upper Xingu, in J Haas (ed). *The Anthropology of War*. Cambridge. Cambridge University Press, 105-24.

Guilbert G 1980. Dinorben Radiocarbon Dates. *Current Archaeology* 70, 336-338.

Haas J 1990. Warfare and the evolution of tribal polities in the prehistoric Southwest,, in J Haas (ed). *The Anthropology of War*. Cambridge. Cambridge University Press, 171-89.

Haas J (ed). 1990. *The Anthropology of War*. Cambridge. Cambridge University Press.

Halliday S P 1985. Unenclosed Upland Settlement in the East and South-East of Scotland, in D Spratt and C Burgess (ed) *Upland Settlement in Britain: The Second Millennium BC and after*. Oxford. British Archaeological Reports 143, 231-52.

Harbison P 1988. *Pre-Christian Ireland*. London. Thames & Hudson.

Harding D W (ed) 1976. *Hillforts - Later Prehistoric Earthworks in Britain and Ireland*. London. Academic Press.

Harding A 1993. Europe and the Mediterranean in the Bronze Age: Cores and Peripheries, in C Scarre and F Healy (ed) *Trade and Exchange in Prehistoric Europe*. Oxford. Oxbow, 153-160.

Harris M 1984. A Cultural Materialist Theory of band and Village Warfare: The Yanomamo Test, in R B Ferguson (ed). *Warfare Culture and Environment*. Orlando, Florida. Academic Press, 111-140.

Hasluck M 1967 The Albanian Blood Feud, in P Bohannon (ed) *Law and Warfare*. New York. Natural History Press, 381-408.

Hawkes C F C. 1948. From Bronze Age to Iron Age: Middle Europe, Italy and the North and West. *Proceedings of the Prehistoric Society* XIV, 196-218.

Hawkes C F C & Smith M A 1955. *Bronze Age hoards in the British Museum*. London. Inventaria Archaeologica G.B. 9-13.

Hawkey R 1991. *Sport Science*. London. Hodder and Stuoghton.

Herity M and Eogan G 1977. *Ireland in Prehistory*. London. Routledge & Kegan Paul.

Hodder I 1986. *Reading the Past*. Cambridge. Cambridge University Press.

Hodder I 1989. Writing Archaeology: Site Reports in Context. *Antiquity* 63, 268-74.

Hodges H 1989 (3rd edition). *Artifacts - An introduction to early materials and technology*. London. Duckworth.

Hodges H W M. 1954. Studies in the Late Bronze Age in Ireland: 1. Stone and Clay Moulds, and Wooden Models for Bronze Implements. *Ulster Journal of Archaeology* 17.

Hodges H W M 1956. Studies in the Late Bronze Age in Ireland, 2. The Typology and Distribution of Bronze Implements. *Ulster Journal of Archaeology* 19.

Hodges H W M 1957. Studies in the Late Bronze Age in Ireland, 3. The Hoards of Bronze Implements. *Ulster Journal of Archaeology* 20.

Hodges H W M 1957. Some Recent Finds of Bronze Implements. *Ulster Journal of Archaeology* 20.

Hodges H W M 1960a. The Bronze Age Moulds of the British Isles, Part 1. *Sibrium* 4.

Hodges H W M 1960b. The Bronze Age Moulds of the British Isles, Part 2. *Sibrium* 5.

Hogg A H A 1972. The Size-Distribution of Hill-Forts in Wales and the Marches, in F Lynch and C Burgess (ed). *Prehistoric Man in Wales and the West*. Bath. Adam and Dart.

Hughes M J, Northover J P and Staniaszek B E P 1982. Problems in the analysis of leaded bronze alloys in ancient artefacts. Oxford Journal of Archaeology 1, 3, 359-64.

James D 1990. Prehistoric Copper Mining on the Great Orme's Head, in P Crew and S Crew S (ed) *Early Mining in the British Isles*. Plas Tan y Bwlch, Snowdonia National Park Study Centre, Occasional Paper No 1, 1-4.

Jobey G 1985. The Unenclosed Settlements of Tyne-Forth: A Summary, in D Spratt and C Burgess (ed) *Upland Settlement in Britain: The Second Millennium BC and after*. Oxford. British Archaeological Reports 143, 177-94.

Jones M U and Bond D !980. Later Bronze Age Settlement at Mucking, Essex, in J C Barrett and R Bradley (ed) *The British Later Bronze Age*. Oxford. British Archaeological Report, British Series 83 (i), 471-481.

Jope E M 1953. Three Late Bronze Age swords from Ballycroghan, near Bangor, Co. Down. *Ulster Journal of Archaeology* 16.

Karsten R 1967 Blood Revenge and War among the Jibaro Indians of Eastern Ecuador, in P Bohannon (ed) *Law and Warfare*. New York. Natural History Press, 303-25.

Kienlin T 1995. *Flanged Axes of the Northalpine Region: An Examination of Use and the Formation of Wear Traces*. MSc. dissertation. Department of Archaeology & Prehistory, University of Sheffield.

Kienlin T L and Ottaway B 1998. Flanged Axes of the Northalpine Region. An Assessment of the Possibilities of Use Wear Analysis on Metal Artifacts, in C Mordant, M Pernot and V Rychner (ed) *L'atelier du bronzier en Europe du XXe au VIIIe siecle avant notre ere, 2.* Paris. CTHS, 271-286.

Knight R W, Browne C and Grinsell L V 1972. Prehistoric skeletons from Tormarton. *Bristol and Gloucester Archaeological Journal* 91, 14-17.

Kristiansen K 1978. The consumption of wealth in Bronze Age Denmark. In K. Kristiansen and C Paludan-Muller (ed), *New Directions in Scandinavian Archaeology*. Copenhagen. National Museum of Denmark.

Kristiansen K 1982. The Formation of Tribal Systems in Later European Prehistory: Northern Europe, 4000-500BC, in C Renfrew, M Rowlands and B Seagraves (ed) *Theory and Explanation in Archaeology*. London.

Kristiansen K 1987. From stone to bronze: the evolution of social complexity in Northern Europe, in E Brumfel and T Earle (ed) *Specialisation, Exchange and Complex Societies*. Cambridge. Cambridge University Press, 30-51.

Kristiansen K 1991. The Emergence of the European World System in the Bronze Age: Divergence, Convergence and Social evolution during the First and second Millennia BC in Europe, in K Kristiansen and J Jensen (ed) *Europe in the First Millennium BC*. Sheffield Archaeological Monographs 6, 7-28.

Kristiansen K 1993. From Villanova to Seddin. the Reconstruction of an Elite Exchange Network during the Eighth Century BC, in C Scarre and F Healy (ed) *Trade and Exchange in Prehistoric Europe*. Oxford. Oxbow, 143-151.

Lawson A J 1979a. A Late Middle Bronze Age hoard from Hunstanton Norfolk, in C Burgess and D G Coombs (ed) *Bronze Age Hoards; some finds old and new*. Oxford. British Archaeological Report 67, 43-71.

Lawson A J 1979b. A Late Bronze Age hoard from West Caister Norfolk, in C Burgess and D G Coombs (ed) *Bronze Age Hoards; some finds old and new*. Oxford. British Archaeological Report 67, 173-9.

Lechtman H 1988. Traditions and Styles in Central Andean Metalworking, in R Maddin (ed) *The Beginning of the Use of Metals and Alloys*. Cambridge, Mass. MIT Press.

Levy J E 1982a. *Social and Religious Change In Bronze Age Denmark*. Ann Arbor. University Microfilms International, Ann Arbor.

Levy J E 1982b. *Social and Religious Organisation in Bronze Age Denmark: an analysis of ritual hoard finds*. Oxford. British Archaeological Report, International Series 124.

Lewis A 1990. Underground Exploration of the Great Orme Copper Mines, in P Crew and S Crew S (ed) *Early Mining in the British Isles*. Plas Tan y Bwlch, Snowdonia National Park Study Centre, Occasional Paper No 1, 5-10.

Lewis A 1998. The Bronze Age Mines of the Great Orme and other sites in the British Isles and Ireland, in C Mordant, M Pernot and V Rychner (ed) *L'atelier du bronzier en Europe du XXe au VIIIe siecle avant notre ere 2.* Paris. CTHS, 45-58.

Litton C D and Buck C E 1995. The Bayesian approach to the interpretation of archaeological data. *Archaeometry* 37, 1, 1-24.

Liversage D and Northover J P 1998. Prehistoric trade monopolies and bronze supply in northern Europe, in C Mordant, M Pernot and V Rychner (ed) *L'atelier du bronzier en Europe du XX^e au VIII^e siecle avant notre ere 1.* Paris. CTHS, 137-152.

Locock M 1999. A late Bronze Age landscape on the Avon Levels: settlement shelters and saltmarsh at Cabot Park, unpublished paper given at an open forum 'Place and Space in the British Bronze Age', Cambridge 24-25 April 1999.

Longley D 1980. *Runnymede Bridge 1976: excavations on the site of a Late Bronze Age settlement.* Guildford. Surrey Archaeological Society Research Volume no 6.

Lynch F and Burgess C (ed) 1972. *Prehistoric Man in Wales and the West.* Bath. Adam and Dart.

MacCullough J A 1992. *Celtic Mythology.* Bury St Edmunds. St Edmundsbury Press.

MacKie E W 1976 The Vitrified Forts of Scotland, in D W Harding (ed) *Hillforts - Later Prehistoric Earthworks in Britain and Ireland.* London. Academic Press, 205-35.

Maddin R (ed). 1988. *The Beginning of the Use of Metals and Alloys.* Cambridge, Massachusetts & London. MIT Press.

Malim T 1999. Place and space in the Cambridgeshire Bronze Age, paper given at an open forum 'Place and Space in the British Bronze Age', Cambridge 24-25 April 1999.

Mallory J P 1991. Excavations at Haughey's Fort 1989-1990. *Emmania (bulletin of the Navan Research Group)*, No 8.

Manley J 1990. A Late Bronze Age landscape on the Denbigh Moors, northeast Wales. *Antiquity* 64, 244, 514-26.

McCauley C 1990. Conference overview, in J Haas (ed). *The Anthropology of War.* Cambridge. Cambridge University Press, 1-25.

McGrail S 1993. Prehistoric Seafaring in the Channel, in C Scarre and F Healy (ed) *Trade and Exchange in Prehistoric Europe.* Oxford. Oxbow, 199-210.

Megaw J V S and Simpson D D A 1979. *Introduction to British Prehistory.* Leicester. Leicester University Press.

Meggitt M 1977. *Blood is Their Argument.* Palo Alto. Mayfield.

Mighall T M 1990. Copa Hill Cymystwyth Preliminary Palaeoecological Observations, in P Crew and S Crew S (ed) *Early Mining in the British Isles.* Plas Tan y Bwlch, Snowdonia National Park Study Centre, Occasional Paper No 1, 65-8.

Mighall T M and Chambers F M 1993. Early Mining and Metalworking: its impact on the environmemt. *Historical Metallurgy* Vol 27, No 2, 71-83.

Milisauskas 1978 *European Prehistory*

Moore J M 1990. Llanymynech Hillfort: a case study in landscape archaeology. Unpublished BA Joint Hons dissertation. University of Manchester.

Moore J M 1992. Llanymynech Hillfort: a palynological and geochemical investigation of ancient mining in the Welsh borders, Unpublished MSc dissertation. University of Sheffield.

Moore W J 1963. *Physical Chemistry*, 4th Edition. London. Longman.

Mordant C, Pernot M and Rychner V (ed) 1998. *L'atelier du bronzier en Europe du XX^e au VIII^e siecle avant notre ere.* Paris. CTHS.

Morren G E B Jr 1984. Warfare on the Highland Fringe of New Guinea: The case of the Mountain Ok, in R B Ferguson (ed). *Warfare Culture and Environment*. Orlando, Florida. Academic Press, 169-207.

Musson C R 1991. *The Breiddin Hillfort: A later prehistoric settlement in the Welsh Marches*. London. Council for British Archaeology Research Report 76.

Needham S P 1979. A pair of Early Bronze Age Spearheads from Lightwater, Surrey, in C Burgess and D G Coombs (ed) *Bronze Age Hoards; some finds old and new*. Oxford. British Archaeological Report 67, 1-39.

Needham S P 1980. An Assemblage of Late Bronze Age Metalworking Debris from Dainton, Devon. *Proceedings of the Prehistoric Society*, 46, 177-215.

Needham S P 1987. The Metallurgical Debris, in D G Buckley and J D Hedges *The Late Bronze Age and Saxon settlements at Springfield Lyons, Essex*. Essex County Council Occasional Paper No 5.

Needham S P 1988. Selective deposition in the British Early Bronze Age. *World Archaeology* 20 #2, 229-248.

Needham S P 1990a. *The Petters Late Bronze Age Metalwork*. London. British Museum Occasional Paper no 70.

Needham S P. 1990b. The Penard-Wilburton Succession: New Metalwork Finds from Croxton (Norfolk) and Thirsk (Yorkshire). The Antiquaries Journal LXX, II, 253-270.

Needham S P 1991a. *Excavation and Salvage at Runnymede Bridge, 1978: The Late Bronze Age Waterfront Site*. London. British Museum Press.

Needham S P 1991b. Middle Bronze Age Spearhead Casting at Grimes Graves, in I H Longworth *Excavations at Grimes Graves, Norfolk, 1972-1976*. London. British Museum Press, 154-87.

Needham S P 1992. The structure of settlement and ritual in the Late Bronze Age of south-east Britain, in C Mordant and A Richard (ed) *L'Habitat et l'Occupation du Sol a l'Age du Bronze en Europe*. Actes du Colloque de Lons-le-Sanier. Paris. Edition du Comite des Travaux historique et scientifiques; Documents Prehistoriques 4, 49-69.

Needham S P 1993(a). Displacement and Exchange in Archaeological Methodology, in C Scarre and F Healy (ed) *Trade and Exchange in Prehistoric Europe*. Oxford. Oxbow 161-9.

Needham S P 1993(b). The Beeston Castle Bronze Age metalwork and its significance, in P Ellis *Beeston Castle , Cheshire - a report on the excavations 1968-85 by Laurence Keen and Peter Hough*. London. English Heritage, 41-50.

Needham S P 1997. Chronology and Periodisation in the British Bronze Age, in K Randsborg (ed). Absolute Chronology: Archaeological Europe 2500-500BC. *Acta Archaeologica 67*.

Needham S P 1998. Modelling the Flow of Metal in the Bronze Age, in C Mordant, M Pernot and V Rychner (ed) *L'atelier du bronzier en Europe du XX[e] au VIII[e] siecle avant notre ere 3.* Paris. CTHS, 285-308.

Needham S P and Ambers J 1994. Redating Rams Hill and reconsidering Bronze Age enclosure. *Proceedings of the Prehistoric Society* 60, 225-243.

Needham S P and Burgess C B 1980. - The later Bronze Age in the Lower Thames Valley: the metalwork evidence. In *The British Later Bronze Age* (ed Barrett J.C. and Bradley R.). Oxford. British Archaeological Report, British Series no 83 (ii), 437-470.

Needham S P and Longley D. 1980. Runnymede Bridge, Egham: a Late Bronze Age riverside settlement, in J C Barrett and R Bradley (ed) *The British Later Bronze Age.* Oxford. British Archaeological Report 83 (ii), 397-436.

Needham S P and Sorensen M L S 1988. Runnymede Refuse Tip: A Consideration of Midden Deposits and their Formation, in J Barrett and I Hinnes (ed) *The Archaeology of Context in the Neolithic and Bronze Age - Recent Trends.* Sheffield. Sheffield University, Dept. of Archaeology & Prehistory, 113-26.

Needham S P, Ramsey C B, Coombs D, Cartwright C and Pettitt P 1997. An Independent Chronology for British Bronze Age Metalwork: The Results of the Oxford Radiocarbon Accelerator Programme. Archaeological Joumal 154, 55-107.

Northover J P 1980. The analysis of Welsh Bronze Age metalwork, in H N Savory *Guide Catalogue of the Bronze Age collections.* Cardiff. National Museum of Wales, 229-236.

Northover J P 1982a. The exploration of the long distance movement of bronze in Bronze and Early Iron Age Europe. *Bulletin of the London Institute of Archaeology* 19, 45-72.

Northover J P 1982b. The Metallurgy of the Wilburton Hoards. *Oxford Journal of Archaeology* 1(1), 69-109.

Northover J P 1988. The Analysis and Metallurgy of British Bronze Age Swords, in I Colquhoun and C Burgess *The Swords of Britain.* Prahistorische Bronzefunde IV, 5. Munich. Beck, 130-146.

Northover J P 1989. Non ferrous metallurgy in archaeology, in J Henderson (ed) *Scientific Analysis in Archaeology and its Interpretation* (ed J. Henderson). Oxford. Oxford University Committee for Archaeology.

Northover J P 1996a. Metal Analysis and Metallography of Early Metal Objects from Denmark, in Vandkilde H *The Metalwork of the Late Neolithic and Earliest Bronze Age in Denmark.* Moesgard. Jutland Archaeological Society, 321-58.

Northover J P 1996b. Comparison of Metal Analyses by Different Laboratories and Methods, in Vandkilde H *The Metalwork of the Late Neolithic and Earliest Bronze Age in Denmark.* Moesgard. Jutland Archaeological Society, 359-367.

Northover J P and Rychner V 1998. Bronze Analysis: Experience of a comparative programme, in C Mordant, M Pernot and V Rychner (ed) *L'atelier du bronzier en Europe du XX[e] au VIII[e] siecle avant notre ere 1.* Paris. CTHS, 19-40.

Oakeshott R E 1960. *The Archaeology of Weapons.* London. Lutterworth.

O'Brien W, Ixer R and O'Sullivan M 1990. Copper Resources in Prehistory: An Irish Perspective, in P Crew and S Crew S (ed) *Early Mining in the British Isles.* Plas Tan y Bwlch, Snowdonia National Park Study Centre, Occasional Paper No 1, 30-35.

O'Connell M. 1986. *Petters Sports Field, Egham: excavation of a Late Bronze Age/Early Iron Age site*. Guildford. Surrey Archaeological Society Research Volume No 10.

O'Connor B. 1980. *Cross-Channel Relations in the Late Bronze Age*. Oxford. British Archaeological Report, International Series 91.

O'Connor B and Cowie T 1995. Middle Bronze Age dirks and rapiers from Scotland: some finds old and new. *Proceedings Of the Society of Antiquaries of Scotland* 125, 345-67.

O'Faolain S 1997. The Technology of Late Bronze Age Sword Production in Ireland, with Special reference to the Experimental Approach, in *A Survey Of Bronze Artefact Production in Late Bronze Age Ireland*. Unpublished MA Dissertation. University of Galway, 154-209.

O'Kelly M J 1989. *Early Ireland*. Cambridge. Cambridge University Press.

Ottaway B S 1982. *Earliest Copper Artifacts of the Northalpine Region*. Bern. Schriften des Seminars fur Urgeschichte der Universitat Bern, Heft 7.

Ottaway B S and Marshall P in prep. Early Copper Metallurgy in Austria and Methods of Assressing its Impact on the Environment. Paper given at the Symposium on *The Beginning of Metallurgy* at Bochum, April 1995.

Otterbein K F 1964. An Analysis of Iroquois Military Tactics. *Ethnohistory* 11,1, 56-63.

Otterbein K F 1967. The Evolution of Zulu Warfare, in P Bohannon (ed) *Law and Warfare*. New York. Natural History Press, 351-7.

Parker Brewis W 1923. The Bronze Sword in Great Britain. *Archaeologia* XXIII, 253-265.

Parker Pearson M 1993. *Bronze Age Britain*. London. Batsford.

Peacock D P S 1969. Neolithic Pottery Production in Cornwall. *Antiquity* 63, 145-9.

Pearce S.M. 1983. *The Bronze Age Metalwork of South Western Britain*. Oxford. British Archaeological Report 120 (i & ii).

Pearce S M 1984. *Bronze Age Metalwork in Southern Britain*. Aylesbury, Bucks. Shire Archaeology.

Pernicka E 1986. Provenance Determination of Metal Artifacts: Methodological Considerations. *Nuclear Instruments and Methods in Physics Research* B14, 24-9.

Pernicka E 1998. Whither metal analysis in archaeology, in C Mordant, M Pernot and V Rychner (ed) *L'atelier du bronzier en Europe du XX^e au VIII^e siecle avant notre ere 1*. Paris. CTHS, 259-68.

Pernicka E, Begemann F, Schmitt-Strecker and Wagner G A 1993. Eneolithic and Early Bronze Age copper artefacts from the Balkans and their relation to Serbian copper ores. Praehistorische Zeitschrift 68,1, 1-54.

Phillips 1980. *The Prehistory of Europe*. London. Allen Lane

Piggott S 1950. Swords and Scabbards of the British Early Iron Age. *Proceedings of the Prehistoric Society* XVI, 1-28.

Polushkin E P 1964. *Structural Characteristics of Metals*. London. Elsevier.

Price B J 1984. Competition, Productive Intensification and Ranked society: Speculations from Evolutionary Theory, in R B Ferguson (ed). *Warfare Culture and Environment*. Orlando, Florida. Academic Press, 209-240.

Pryor F 1982. *Fengate*. Princes Risborough. Shire Archaeology.

Pryor F 1991. *Flag Fen - Prehistoric Fenland Centre*. London. Batsford.

Pryor F 1992. The Fengate/Northey landscape. *Antiquity* 66; 251, 518-531.

Pryor F 1996. *British Archaeological Awards 1996 lecture: Archaeology and the Public*. http://britac3.britac.ac.uk/cba/projects/baalect.html

Pryor F 1998. *Farmers in Prehistoric Britain*. Stroud, Glos. Tempus.

Raftery B 1971. Rathgall, Co Wicklow: 1070 excavations. *Antiquity* XLV, 296-8.

Raftery B 1976. Rathgall and Irish Hillfort Problems, in D W Harding (ed) *Hillforts - Later Prehistoric Earthworks in Britain and Ireland*. London. Academic Press, 339-58.

Raftery B 1982. Two Recently Discovered Bronze Shields from the Shannon Basin. *Journal of the Royal Society of Antiquaries of Ireland* 112.

Ramsey W G 1989. *Middle Bronze Age Weapons in Ireland*. Unpublished PhD Thesis. Queen's University Belfast.

Ramsey W G and Simpson D D A 1990. A Collection of Prehistoric Bronzes from Ballymoney, Co. Antrim. *Ulster Journal of Archaeology* 53.

Rappaport R A 1968. *Pigs for the Ancestors*. New Haven. Yale University Press.

Rayner T 1995. *Casting bronze axe heads into clay moulds: the method and analysis - an archaeological perspective*. Unpublished B Dissertation. University of Sheffoeld.

Read D W 1982. Toward a Theory of Archaeological Classification, in R Whallon and J Brown (ed) *Essays on Archaeological Typology*. Evanston, Illinois. Center for american Archaeology Press, 56-91.

Renfrew A C 1972. *The Emergence of Civilisation. The Cyclades and the Aegean in the third millennium BC*. London. Methuen.

Renfrew C. 1973 *Before Civilisation*. London. Jonathan Cape.

Renfrew C 1982. Socio-economic change in ranked societies, in C Renfrew and S Shennan (ed) *Ranking Resource and Exchange - aspects of the archaeology of early European society*. Cambridge. Cambridge University Press, 1-8.

Renfrew C and Bahn P 1991. *Archaeology: Theories, Methods and Practice*. London. Thames & Hudson.

Renfrew C, Dixon J E and Cann J R 1968. Further analysis of Near Eastem obsidians. *Proceedings of the Prehistoric Society* 34, 319-31.

Renfrew C and Shennan S (ed) 1982. *Ranking Resource and Exchange - aspects of the archaeology of early European society*. Cambridge. Cambridge University Press.

Robarchek C 1990 Motivations and material causes on the explanation of conflict and war, in J Haas (ed). *The Anthropology of War*. Cambridge. Cambridge University Press, 56-76.

Robbiola L et Fiaud C 1992. Apport de l'analyse statistique des produits de corrosion a la comprehension des processus de degradation des bronzes archaeologiques. *Revue d'Archaeometrie* 16, 109-119.

Rohl B M 1995. *Application of Lead Isotope Analysis to Bronze Age Metalwork from England and Wales*. Unpublished D. Phil. thesis. University of Oxford.

Rosenfeld A 1965. *The Inorganic Raw Materials of Antiquity*. London. Weidenfield and Nicolson.

Rothenberg B (ed) 1990. *The Ancient Metallurgy of Copper*. London. IAMS.

Ross J B 1984. Effects of Contact on Revenge hostilities among the Achuara Jivaro, in R B Ferguson (ed). *Warfare Culture and Environment*. Orlando, Florida. Academic Press, 83-109.

Rowlands M J 1976. *The Organisation of Middle Bronze Age Metalworking*. Oxford. British Archaeological Report 31 (i & ii).

Rowlands M J, Larsen M T and Kristiansen K, 1987. *Centre and Periphery in the Ancient World*. Cambridge. Cambridge University Press.

Savage R D A 1979a. Technical Notes on the Watford Sword Fragments, in C Burgess and D G Coombs (ed) *Bronze Age Hoards: some finds old and new*. Oxford. British Archaeological Reports 67, 221-8

Savage R D A 1979b. Metallographic Examination of Two Spear Heads from the Watford Hoard, in C Burgess and D G Coombs (ed) *Bronze Age Hoards: some finds old and new*. Oxford. British Archaeological Reports 67, 229-33.

Savory H N 1948. The 'Sword-bearers'. a Reinterpretation. *Proceedings of the Prehistoric Society* XIV, 155-175.

Savory H N 1949. The Atlantic Bronze Age in South-west Europe. *Proceedings of the Prehistoric Society* XV, 128-155.

Savory H N 1971. A Welsh Bronze Age Hillfort. *Antiquity* XLV, 251-261.

Savory H N 1976. Welsh Hillforts: A Reappraisal of Recent Research, in D W Harding (ed) *Hillforts - Later Prehistoric Earthworks in Britain and Ireland*. London. Academic Press, 237-92.

Savory H N 1980. *Guide Catalogue of the Bronze Age Collections*. Cardiff. National Museum of Wales.

Scarre C and Healy F (ed) 1993. *Trade and Exchange in Prehistoric Europe*. Oxford. Oxbow.

Scott D 1987. *Case Studies in the Metallographic Examination of Ancient Metallic Artefacts*. London. Summer Schools Press.

Scott D 1991. *Metallography of Ancient Metallic Artefacts - Course Handbook*. London. Summer Schools Press.

Sharples N 1991. Warfare in the Iron Age of Wessex. *Scottish Archaeological Review* 8.

Shennan S 1982. The emergence of hierarchical structure, in C Renfrew and S Shennan (ed) *Ranking Resource and Exchange - aspects of the archaeology of early European society*. Cambridge. Cambridge University Press, 9-12.

Shennan S 1982. From minimal to moderate ranking, in C Renfrew and S Shennan (ed) *Ranking Resource and Exchange - aspects of the archaeology of early European society*. Cambridge. Cambridge University Press, 27-32.

Shennan S 1988. *Quantifying Archaeology*. Edinburgh. Edinburgh University Press.

Shennan S 1993. After social evolution: a new archaeological agenda? in N Yoffee and A Sherratt (ed) *Archaeological Theory; who sets the agenda?* Cambridge. Cambridge University Press.

Sherratt A 1982. Mobile resources: settlement and exchange in agricultural Europe, in C Renfrew and S Shennan (ed) *Ranking Resource and Exchange - aspects of the archaeology of early European society*. Cambridge. Cambridge University Press, 13-26.

Sherratt A 1996. Why Wessex? The Avon Route and River Transport in Later British Prehistory. *Oxford Journal of Archaeology* 15(2), 211-34.

Simpson D D A 1986. A Late Bronze Age Sword from Island Mac Hugh, Co. Tyrone. *Ulster Journal of Archaeology 49*.

Slater E A and Charles J A 1970. Archaeological Classification by Metal Analysis. *Antiquity* XLIV, 207-13.

Spencer P 1965. *The Samburu*. Routledge & Keegan Paul. London.

Spratt D and Burgess C 1985. *Upland Settlement in Britain: The Second Millennium BC and after.* Oxford. British Archaeological Reports 143.

Stanford S C 1972. The Function and Population of Hill-forts in the Central Marches, in F Lynch and C Burgess (ed). *Prehistoric Man in Wales and the West*. Bath. Adam and Dart, 307-344.

Staniasek B E P and Northover J P 1982. The Properties of Leaded Bronze Alloys. *Proceedings of the 22nd Symposium on Archaeometry, University of Bradford*, 262-272.

Stead I M 1968. An Iron Age Hill-Fort at Grimthorpe, Yorkshire, England, Proceedings of the Prehistoric Society XXXIV, 148-90.

Stos-Gale Z A 1989. Lead isotope studies of metals and the metal trade in the Bronze Age Mediterranean, in J Hemderson (ed) *Scientific Analysis in Archaeology*. Oxford University Committee for Archaeology, Monograph No 19. Oxford.

Taylor M 1992 Flag Fen: the wood. *Antiquity* 66, 251, 476-498.

Taylor R J 1993. *Hoards of the Bronze Age in Southern Britain*. Oxford. British Archaeological Report 228.

Thomas R 1989. The Bronze-Iron Transition in Southern England, in M L S Sorensen and R Thomas (ed) *The Bronze Age-Iron Age Transition in Europe*. Oxford. British Archaeological Report, International Series 483, 263-286.

Timberlake S 1990a. Excavations at Parys Mountain and Nantyreira, in P Crew and S Crew S (ed) *Early Mining in the British Isles*. Plas Tan y Bwlch, Snowdonia National Park Study Centre, Occasional Paper No 1, 15-21.

Timberlake S 1990b. Excavations and Fieldwork on Copa Hill Cwmystwyth 1989, in P Crew and S Crew S (ed) *Early Mining in the British Isles*. Plas Tan y Bwlch, Snowdonia National Park Study Centre, Occasional Paper No 1, 22-9.

Timberlake S and Switsur R 1988. An Archaeological Investigation of Early Mineworkings on Copa Hill, Cwmystwyth: New Evidence for Prehistoric Mining. *Proceedings of the Prehistoric Society* 54, 329-33.

Tomalin D 1982. Bronze Age swords of the Ballintober type found at Mixnams Pit, Thorpe, Surrey. *Surrey Archaeological Collections* 73, 163-7.

Trump B A V 1960. Daggers, Dirks and Rapiers of the Scottish Middle Bronze Age. *Proceedings of the Society of Antiquaries of Scotland* 93, 1-15.

Trump B A V 1962. The Origin and Development of British Middle Bronze Age Rapiers. *Proceedings of the Prehistoric Society* 28, 80-102.

Turney-High H 1971. *Primitive War.* Columbia. University of South Carolina.

Tylecote R F 1968. Metallographic Examination of Bronze Age Artifacts from the North of England, in C B Burgess *Bronze Age Metalwork in Northern England.* Newcastle-upon-Tyne. Oriel Press.

Tylecote R F 1970. The Composition of Metal Artifacts: A Guide to Provenance? *Antiquity* XLIV, 19-25.

Tylecote R.F. 1976. *A History of Metallurgy.* London.

Tylecote R F 1983. The Metallurgical Examination of some pieces from the Gilmonby Hoard, in D Coggins *A Hoard of Late Bronze Age Metalwork from Gilmonby, near Bowes, Co Durham.* The Bowes Museum archaeological reports 2.

Tylecote R.F. 1987. *The early history of metallurgy in Europe.* Longman. London.

Tylecote R F and Northover J P 1990. The Metallurgy of the Petters Bronzes, Metallographic Study, in S P Needham *The Petters Late Bronze Age Metalwork.* London. British Museum Occasional Paper no 70, 89-96.

Tylecote R F and Biek L 1991. Metal-working evidence, in C R Musson *The Breiddin Hillfort: A later prehistoric settlement in the Welsh Marches.* London. Council for British Archaeology Research Report 76, 147-8.

Tyler D 1993. *A reassessment of the interpretation of the mechanical properties and the micro structure of tin-bronzes based on the use of experimental techniques.* BSc Dissertation. Department of Archaeology and Prehistory, University of Sheffield.

Vander Voort G F 1984. *Metallography, Principles and Practice.* New York. McGraw-Hill.

Varndell G L 1979. The Andover Hoard - A Late Bronze Age Hoard of Wilburton Tradition from Hampshire, in C Burgess and D G Coombs (ed) *Bronze Age Hoards; some finds old and new.* Oxford. British Archaeological Report 67, 93-7.

Vayda A P 1967. Maori Warfare, in P Bohannon (ed) *Law and Warfare.* New York. Natural History Press, 359-80.

Vayda A P 1976. *War in Ecological Perspective.* New York & London. Plenum Press.

Voce E 1975. Bronze Casting in Ancient Moulds, in H H Coghlan *Notes on the Prehistoric Metallurgy of Copper and Bronze in the Old World.* Occasional Papers on Technology, 4, second edition. Oxford. Oxford University Press.

Vogel A 1978. *Textbook of Quantitative Inorganic Analysis*, 4th Edition. London. Longman.

Wager E 1994. *A Copper Based Archaeometallurgical Investigation.* Unpublished BSc Dissertation University of Sheffield,

Welham K 1997. *Investigation into the Segregation of Lead in Cast Lead Tin Bronzes.* Unpublished Dissertation (part of MSc), University of Sheffield.

Whitehead N L 1990. The Snake Warriors - Sons of the Tiger's Teeth: a descriptive analysis of Carib warfare, ca. 1500-1820,, in J Haas (ed). *The Anthropology of War.* Cambridge. Cambridge University Press, 146-70.

Wilde W R 1857/1861/1862. *Catalogue of Antiquities in the Museum of the Royal Irish Academy.* Dublin.

Williams B B 1978. Excavations at Lough Eskragh, County Tyrone. *Ulster Journal of Archaeology* 41.

Yates D 1999 Bronze Age field systems in the Thames Valley and Estuary, paper given at an open forum 'Place and Space in the British Bronze Age', Cambridge 24-25 April 1999.

Zimmerman L 1997. The Crow Creek massacre, archaeology and prehistoric Plains warfare in contemporary perspective, in J Carman (ed) *Material Harm - archaeological studies of war and violence.* Glasgow. Cruithne Press, 75-94.