# The Compleat Metalsmith: Craft and Technology in the British Bronze Age

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## ABSTRACT

This thesis explores the craft of metallurgy in the British Bronze Age through an examination and analysis of metalworking tools.

The goal of this research was to reassemble the Bronze Age metalsmithing toolkit based on an understanding of the craft and its practice. The first chapters examine the smith and metalsmithing tools through literary sources to establish a theoretical framework for understanding the significance of tools and smiths in the British Bronze Age.

This is followed by a study of metalsmithing tools in museum collections. These examinations focussed on wear, design, and chemical composition. Tools were cross-referenced to contemporary tools, descriptions from ethnographic literature, and tools in modern workshops.

This research also supplied data to create replica tools for use in an experimental programme to explore tool use and performance. The research culminated in establishing a system called Minimum Tools Required (MTR). It is based on the idea that the presence of an object implies the existence of the tools and materials necessary for its manufacture, and that the presence of tools implies a purpose, and the possibility of other tools and materials that are associated with that purpose. Using this system provides a means to assess assemblages and aids in understanding the kind and the number of tools and materials that were a necessary part of the Bronze Age metalsmith's toolkit.

The system also allows for more precise interpretations to be made of hoards. Tools can indicate the types of metal objects being made, or represent specific metalsmithing tasks. Thus by recognising the tools and their function, statements can be made about how these tools were used and the processes by which metal objects were made in the Bronze Age, resulting in a more complete understanding the organisation of the metalsmith's craft in antiquity.

# PREFACE AND ACKNOWLEDGEMENTS

*Discovery is art, not logic*

C.S. Smith 1981, 347

**My background as an artisan**

For many a thesis and the resulting PhD is the beginning of a career. For me it is the culmination of years of experience as a jeweller and metalworker.

The knowledge of metalworking, its traditions, tools, and techniques have been passed from teacher to student more than three thousand years. I am indebted to my teachers, because the skills I learned are necessarily experiential and cannot be acquired from reading books. As a student at the Milwaukee Area Technical College, I learned the properties of metals while stretching flat sheets of copper into round bowls. My teachers instructed me on the mechanical properties and the microcrystalline structure of metal; how metal fatigue will cause an object to crack if I continued working and that annealing will relax the metal so that the work can continue.

Metallography is not the same as metalsmithing. The changes in metallic structure can be seen under the microscope in polished samples, but in order to be a metalsmith, I had to feel the tension in the metal as I worked it. When the metal became stressed, I needed to feel how the hammer bounces back slightly differently, that the sound of the hammer striking the metal will change as the metal becomes more rigid. When it is time to anneal the metal I can use a thermocouple and pyrometer, but I needed also to know that the piece was nearing the proper temperature for annealing when the rainbow colours on the surface of the metal coalesced to a cherry red. To those who do not know these subtle signals, the embodied knowledge of the metalworker appears to be a form of magic.

In 2005 I decided to return to university to finish a degree in anthropology. While working in the labs at the University of Minnesota, I was given the opportunity to work with a collection of bronze axes. I was fascinated by them and plunged into the Bronze Age technology. The anthropology department did not have facilities to cast bronze so I introduced myself to Wayne Potratz, master of the foundry in the art department. While he was accustomed to sculpture students, he became interested in my questions about ancient alloys and recipes for clay moulds. We successfully cast axes and palstaves. I also produced some spectacular failures, but each one was a learning experience.

When I studied for my master's degree at the University of Sheffield, I learned more of the mechanical properties of metal, but found that other than casting, few archaeologists had explored metalsmithing tools or smithing techniques. Once again I plunged into the world of metalworking, exploring tools that were both

familiar and different than the ones I had used most of my adult life. As a metalsmithing student I was told that the tools I used had their origins in Medieval Europe. Little did I know that their pedigree went so much further back in time.

The use of modern analytical equipment has given me the opportunity to see metals in a way that was impossible for early metal workers. However, despite the technological advances, I still need to understand the material as they did: by pumping bellows, watching flames, and feeling the hammer as I work the metal.

This thesis has been a labour of love, but that is not to say that it has been easy. In the second year I of my PhD I had to make some radical changes. I was determined to regain control of my work, and in order to do this I realised that I had to abandon most of what I had written and start fresh. I quickly outlined the thesis that is presented here with modifications suggested by Dr Caroline Jackson and Dr Bob Johnston, both of whom I am indebted to for their support, patience, and for taking me on as a student on such short notice.

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> Everyone must leave something behind when he dies, my grandfather said. A child or a book or a painting or a house or a wall built or a pair of shoes made. Or a garden planted. Something your hand touched some way so your soul has somewhere to go when you die, and when people look at that tree or that flower you planted, you're there.
>
> It doesn't matter what you do, he said, so long as you change something from the way it was before you touched it into something that's like you after you take your hands away. The difference between the man who just cuts lawns and a real gardener is in the touching, he said. The lawn-cutter might just as well not have been there at all; the gardener will be there a lifetime."
>
> - Ray Bradbury *Fahrenheit 451*

# CONTENTS

# TABLE OF FIGURES

# List of Tables

## ABBREVIATIONS USED IN THIS THESIS

AN (Ashmolean)

BM (British Museum)

BOW (Bowes Museum)

COLEM (Colchester Museum Services)

CPMR (Clifton Park Museum, Rotherham)

DZSWS (Wiltshire Heritage Museum in Devizes)

IOW (Isle of Wight Heritage Service Museum Service)

NM (Northampton Museum)

NWHCM (Norwich Castle Museum)

PL (Proper Left, the object's left)

PR (Proper Right, the object's right)

SSWM (Salisbury & South Wiltshire Museum)

SOUMS (Southend Museums Services)

TM (Taunton Museum)

WMS (Winchester Museums Services)

WPM (Weston Park Museum, Sheffield)

SEHS (St Edmundsbury Heritage Service)

SSW (Salisbury & South Wiltshire Museum)

# Chapter 1 LAYING OUT THE TOOLS IN PREPARATION FOR WORK

> *Changes in technology change how man communicates, how he feeds, clothes, houses, and amuses himself—and, most important, what he thinks about. Despite popular clichés, technology has been a fully human experience, with both sensual and intellectual attributes, working to fulfil the practical and aesthetic needs of society.*
>
> *~Cyril Stanley Smith (1981, 348)*

## THE SIGNIFICANCE OF TOOLS

Tools are the embodiment of skill. They represent the coordinated actions performed in the creation of objects and are the link between mind, body, and creation. Tools are designed to facilitate a task and their presence indicates skilful use in the mastery of a craft (Untracht, 1985, 26-7).

Many books and articles have been written on the pyrotechnical processes of early metalworking including smelting (Bamberger, 1992, Craddock, 1995, Timberlake, 2005, Amzallag, 2009), casting (Tylecote, 1962, Roberts and Ottaway, 2003, Bayley et al., 2008), and the significance of the transformative aspects of melting and recycling (Brück, 2001b), however, in archaeological literature little has been written about other aspects of metalworking. Coghlan briefly catalogued metalworking techniques, but this was in 1951, when few tools from the Bronze Age were recovered. Other studies are brief and narrowly focussed, such as Oddy's work on wire production (1977) and Maryon's article on metalworker's tools (1938).

In terms of time and the number of tools necessary to complete tasks, the metalworking techniques discussed in this thesis would constitute the major part of the labour of the Bronze Age metalsmith. While pouring molten metal and breaking open a mould is a matter of a minute's work, removing excess metal, cleaning, polishing, and finishing an object can mean hours of labour. In addition, not all metal objects were cast. Many ornaments and sheet metal objects were fabricated using tools and techniques described in this thesis. While fabrication and forging might not be as exciting as pyrotechnical techniques, understanding these aspects of the craft is necessary for the interpretation of the tools, objects, and the work of metalsmiths in the Bronze Age. This thesis aims to narrow these gaps in metalworking information by recognising the tools and techniques used to manufacture metal objects from the Bronze Age in Britain.

Studies such as those written by Coghlan (1951), Tylecote (1992), and the studies cited above focus on the metalworking processes, and how metalworking tasks could have been accomplished. However, the careful examination of these tools and their condition gives valuable information that provides insight into how the tools were used, cared for, and handled. Using this information the focus can be turned from the task and instead can be used to make statements about Bronze Age metalsmiths as artisans who used these tools to perform metalworking tasks.

The Bronze Age metalsmithing tools examined in this thesis are all we have that connects the smith and the metal objects seen in museums. These hammers, chisels, anvils, along with other tools of the craft are essential clues as to how metalsmithing was practiced in antiquity, but have rarely been acknowledged as a resource for the study of prehistoric metallurgy. By studying the tools used by metalsmiths, questions can be addressed about their design and use, if there are regional traditions for particular types of tools, if there are patterns of deposition, and if they had symbolic meaning. The study of tools tells us both about how metal objects were manufactured, but can also shed light on the smith and metalworking practice. This thesis will address questions about the types of metalsmithing tools found in Britain; how they were used, and their significance as the defining objects in hoards.

To achieve these goals, a two-fold approach is proposed to identify and systematically organise metalworking tools, and to ascertain the way in which these tools could have been used. The thesis will do this by first presenting a literature based assessment of smiths as seen through ethnographic studies and their presence in myths and legends. This is complemented by a theoretical framework that establishes the processes whereby metals could accrue value in prehistory. In Chapters 2 and 3, a theoretical framework is proposed that explores smiths through ethnographic studies and myths surrounding non-ferrous metalworking. Chapter 2 examines mythological and ethnographic examples of the roles that smiths play in their communities. Issues such as itinerancy and the role of the smith as a secular or religious leader are also addressed. Chapter 3 explores how metal could have been valued, both as objects in daily use and as artefacts deposited in hoards. These chapters both challenge and define some archaeological theories concerning smiths and their craft. They provide a basis for understanding the symbolic power of tools in hoards, and how tools might have been used as indicators of power or prestige.

The second half of the thesis presents a practical approach where metalsmithing tools have been examined and organised by function, and then used as a reference for a programme of experimental work.

Chapter 4 concentrates on smithing tools and provides typologies based on function. In Chapter 5 the tools are located in museum collections and are examined for wear. In addition, a select number of the tools were chemically analysed. This data was then employed to create replica tools that were used in a programme of experimental work (Chapter 6).

Chapter 7 presents an organisational framework that can be used to recognise metalsmithing tools and how they are a part of the craft. This system will be applied to various metalworking techniques and can be used to ascertain what kinds and quantities of tools and materials that are necessary to complete a metal object. The chapter will also address depositional practices and how context can be used to understand Bronze Age metalworking techniques. The chapter will also address the context of metalsmithing tools and how this might represent the significance of the smith in the Bronze Age.

## ARCHAEOLOGISTS AND METALSMITHING

Metals have had a defining role in ordering history and prehistory. Both Ovid (2000 Book 1, lines 89-150) and Hesiod (1914 lines 109-201) wrote about the ages of man that were identified by metals, beginning with gold and progressing through silver, bronze and iron. Later in 1816, Thomsen systematically organised prehistory into ages of stone, bronze, and iron (Heizer, 1962). Because of this, metal objects were valued not only for their worth as antiquities, but as objects that could be used as an indicator of status, and for assigning broad dates for assemblages and sites.

Early authors writing in archaeology were unfamiliar with metal working processes and as a result many assumptions were made about the technological ability of early smiths. Lubbock was one such author whose ideas seem hindered by his lack of understanding of metalworking. He believed that Bronze Age metal workers were unable to drill rivet holes in bronze, and that steel tools were required for finishing bronze objects (Lubbock, 1869, 40). Lubbock and Childe both believed that similarity of design must indicate the work of a single artisan (Lubbock, 1869, 58, Childe, 1940, 118) when it is very likely that a finished object could have been used to make countless moulds to create duplicate objects (Coghlan, 1951, 49, Tylecote, 1962, 123). Although Childe does describe this process, he does not apply it to the idea that similar objects could have been reproduced in different localities by different smiths (Childe, 1930, 172, Budd and Taylor, 1995, 137).

Such misconceptions were addressed by Ronald Tylecote, a professional metallurgist, who wrote extensively on ancient metallurgical technology. He developed archaeometric techniques to better understand ancient metallurgy by using a scientific approach to investigate microstructure and chemical composition. These techniques brought about significant insights into the production processes of materials and fabrication methods (Tylecote, 1962, 1986, 1992). Tylecote's work inspired further studies and was instrumental in the development of the field of archaeometallurgy. This was a critical development in the understanding of the value of metals as a subject for study in archaeology.

The study of metals and metalworking incorporates a broad field of interests that includes metallography, metallurgy, and experimental work along with more traditional interests such as typological and chronological studies, in addition to defining status in burials (Coles, 1973, Burgess, 1974, Tylecote, 1962, Tylecote, 1986, Tylecote, 1992, Reynolds, 1999, Shell, 2000).

Experimental work done by Coles and others took archaeometallurgy out of the lab, and explored metalworking practices in situations closer to Bronze Age conditions (Coles, 1973, Reynolds, 1999). These experiments ranged from casting bronze in outdoor furnaces to using replica weapons to test their durability.

Most recently, in *Metals and Metaworking: A Research Framework* (Bayley et al., 2008, 68), the authors  made an assessment for future research in archaeometallurgy and summarised what is known about the prehistory and history of the field. The agenda recognised the need to 'develop research approaches to the processes of invention, innovation, and technological processes'. However, most of these studies have concentrated on casting, smelting, and alloying technology, omitting other aspects of metalworking such as forging and forming along with the tools necessary for performing those tasks.

In Britain, metalworking tools are frequently relegated to a 'miscellaneous category' in which they are ignored or given minimal attention. Much has been written on the cultural significance of agricultural tools in archaeology such as axes (Clarke et al., 1985, Scott, 1989, Bradley, 1998, Turner, 1998a, Roberts and Ottaway, 2003). Modern ethnographic studies have highlighted the cultural importance of smithing tools (see Chapter 2) however in the field of archaeology metalworking tools have received little attention.  It could be the case that hammers, chisels, and other tools are considered utilitarian objects that have not been associated with the idea of elite in the same way that weapons or ornaments are, and for that reason they have not been subject to as much study as other metal objects. No metalsmithing workshops or sites have been discovered from the British Bronze Age, and outside of a few stray finds, these tools are found in hoards, an unusual context, where they are interpreted to be a part of the assemblage that defines it as a hoard associated with metalsmithing. The result is that the tools are reduced to a marker to define a particular type of hoard with a focus on why the hoard was deposited (cache of tools and supplies, votive offering), rather than being recognised as a set of tools to perform specific metalworking tasks.

In all the typologies and categorisations of Bronze Age metallurgy, the tools of the smith are barely commented upon, and instead statements about smiths are based predominantly upon data gleaned from the objects they produced or the waste products left over from casting. While swords and axes have been examined for the minutest differences, there is no published typology for British Bronze Age hammers. Archaeologists have not recognised metalsmithing tools as an important resource that would enable the discipline to understand metalworkers, their craft, and their role in their communities. Such information could indicate if there were specialised tools for different types of metalworking, or if there were regional differences. Of all objects, tools should be singled out for their significance as these were made, used, and cared for by the metalsmith on a regular basis.

Unlike pottery manufacture or weaving, metalsmiths cannot practise their craft without their tools. Tools are necessary for every phase of production. Molten metal must be contained within a crucible that the smith holds with tongs. Sheets of metal cannot be worked or decorated by hand; the tasks must be accomplished using chisels, hammers, and anvils. Tools become prostheses, extensions of the smith that makes the craft of metalsmithing possible. The study of tools as a medium becomes the first step in understanding both the artisan and the craft (McLuhan, 1994, 139). Robert Aunger (2010) explored the technology of tools and tool making, and defined tools as technological objects that have been made with intent and a "mental representation" of the object's final form. He defined technology as an artefact based interaction in "particular contexts of engagement". Further, this process is seen to be controlled by an agent who creates an object based on prior knowledge of how well the object can fulfil a function that is consistent with the original intent of the object's designer. This is also embedded in social processes and while not always evident, the technology of tools influences how tasks are accomplished, and shapes how humans think about performing these tasks (Bijker, 2010, 65, 67). Bleed (2001, 122) recognised that there was a need for archaeologists to identify the connections made by people in the past that led to the sequences by which these tasks were accomplished. This thesis recognises the significance of tools, both as utilitarian objects, but also as culturally significant objects and aims to address those aspects of metalworking that have not formerly been explored by archaeological studies. This will be done by examining current ethnographic studies of metalsmiths and their tools (Chapter 2) and considering these when examining the contexts and condition in which we find Bronze Age metalsmithing tools (Chapters 4 and 5). Thus, rather than basing the interpretation of a hoard solely based on its contents, the tools can be examined to interpret the hoard, recognising the hoard as a significant factor in understanding metalsmithing as it was practised in the British Bronze Age.

Because tools are the primary evidence of how metalwork was practiced in the Bronze Age, they can provide essential information about how metal objects were made, how metalworking technology changed, and their presence in hoards can point to the cultural significance of the smith and smithing.

## THE SMITH AND TOOLS IN THE BRITISH BRONZE AGE

Unlike pottery studies where the hands of the potter are evident in objects they make, similar actions have not been recognized in metal crafting. The fingerprints of potters can be seen imprinted and preserved in fired clay; however by studying the minute imperfections in metal objects we can see the hands of the metalsmith (**Fig 1.1**). A momentary distraction can result in a hammer blow that is harder than the previous one creating a line where the chisel bites deeper into the metal. These permanent imprints of gestures come as close as possible to watching the hands of the metalsmith at work. They give us a glimpse of the interaction of tools, materials, and the metalsmith's hands.

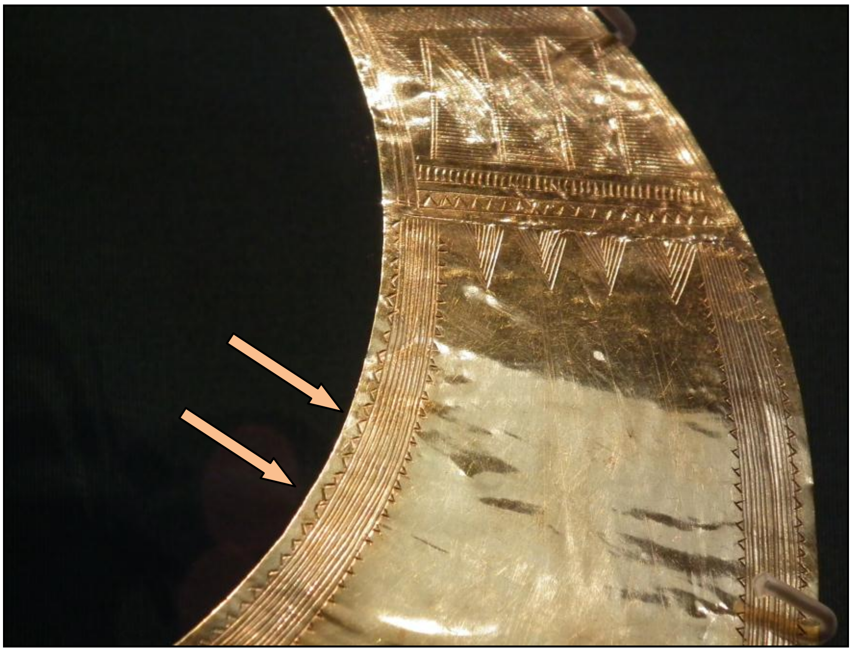


**Figure 1.1 Close-up of chasing work on a gold lunula. Compare the imperfections in the zig-zagged border between the arrows to the near perfect chasing on the rest of the piece. (Photograph by the author © Trustees of the British Museum)**

During the course of writing this thesis I met a master silversmith who preferred to work with archaic hand tools rather than more modern electric equivalents. Many of his tools were decades old, and were worn in a way that had become comfortable to his hands. But his hands also had become worn and calloused in a way that showed they had adapted to the tools and the manner in which he did his work. The tools and the smith had moulded each other in a way described by Tim Ingold, as the craft and crafter are bound together in a reflexive relationship of creation (Ingold, 2000, 347). These tools are an essential component of this relationship and are the key means for enabling us to visualise the relationship between smiths, their tools, and the finished metal objects. The connection that binds the smith with the tools and objects points to the significance of tools in understanding Bronze Age smiths and their work. This thesis explores the connection and reflexive relationship between smiths and their tools. It demonstrates how these tools can function both as utilitarian and as magical objects; and in turn how they are used to create practical objects, or powerful and valuable pieces that can symbolically hold power and confer it upon others (Chapter 3). This relationship can also be seen in the studies of myths and ethnography in Chapter 2, where the smiths' craft sets them apart, often placing them among gods, healers, and shamans. The chapter will also examine the roles in ritual life played by smiths and their connection to smith-gods and the origins of metalworking. Together these chapters will provide a means for understanding the role of the smith in the Bronze Age, both as an artisan and as a significant member of society connected to myth and ritual practices.

## THE SMITH AND METALS IN RITUAL PRACTICE

Chapter 3 examines how metal becomes valued and how it is important in non-monetary societies. This in part is due to social beliefs regarding power ascribed to metal and smiths, and the role of metal in ritual. Post-enlightenment society divided religion from science, and since then ritual has languished in the realm of the illogical, superstitious, and incomprehensible; and was seen to be separated from daily life (Brück, 1999a, 313, Barber, 2001, 164, Falchetti, 2003, 12 ff, Marchand, 2008, 2). However, ignoring the ritual aspects of early society is tantamount to ignoring the underpinnings of its social structure. Even today religion plays a major role influencing political power and social structure. If we cannot ignore the role of Christianity and Islam in the development of modern society, then how can we avoid the serious investigation of the ritual aspects of prehistory?

More recent studies have blurred the division between ritual and non-ritual activities (Brück, 1999a, 319, Fogelin, 2007, 70). Rituals have purpose and structure (Fogelin, 2007, 58) and those elements used as part of a ritual are chosen for specific reasons ranging from representations of culturally significant beliefs to symbols of disciplinary practice (Sax, 2010, 5). Ethnographic studies of non-ferrous metalworkers in West Africa (Neaher, 1979) and India (Lahiri, 1995) show how ritual permeates daily life and how metal is a part of that, either as powerful ritual objects or as valued objects that contain the potency of the spirit of the smith (Chapter 3).

## TYPOLOGIES AND EXAMINATION: ORGANISING AND UNDERSTANDING METALWORKING TOOLS

To create a framework for organising and understanding Bronze Age smithing tools, this study sought to examine all of the available metalworking tools in Britain. These were located using a variety of sources as described in Chapter 4, and objects were examined in museums throughout Britain. When assemblages of tools were examined in museum collections, it was soon apparent that, based upon the author's knowledge of non-ferrous metalworking, only a portion of the tools necessary for creating metal objects in the Bronze Age had been recovered. It may be that many metalworking tools would have been lost to recycling in antiquity, while others might have deteriorated in the burial environment, or they have not yet been recovered. The initial objective was therefore to develop an organisational framework that would provide an inventory for the tools and materials necessary to create metal objects based on metalsmithing practices. Such information could enable archaeologists to understand the processes of metalworking, to recognise what objects might be missing from a metalworking assemblage, or to identify possible metalworking tools recovered from excavations or in museum collections. Ultimately the greatest benefit of this research will be a more complete knowledge of Bronze Age metalworking and how it was practised.

This programme of searching for and identifying as many metalworking tools as possible provided a basis for recognising variation of tool types. Of particular importance was the specific attention paid to the working faces of the tools. Focusing on the function of tools placed them in various processes of metalsmithing and as integral parts of the metalsmith's toolkit. The tools were then compared to contemporary and modern tools with the hope of ascertaining if there are any counterparts that will give further information about how they were used (Chapter 4).

While Bronze Age material culture studies and other reports have shown the close association between Britain, the north of France and the low countries (O'Connor, 1980a, Rowlands, 1980, Muckelroy, 1981) few comparative studies have been done examining the metalsmithing tools of Britain, Ireland and the continent to see if they could also be used to further understand cultural connections (Jöckenhovel, 1982, Jantzen, 2008). For this thesis, some examinations of Irish tools were undertaken and used as examples for interpretation (Chapter 7). However, in order to focus on a discreet sampling of tools, this thesis limited typological examination and quantitative analysis to tools found in England and Scotland.

Since tools cross craft categories, care was necessary in identification; a single tool can have multiple functions. An object such as a woodworking chisel closely resembles a chasing tool for decorating metal, but it could also function as a tool for leatherworking or carving stone. The examination of tool design and use-wear provides insight into how a tool was used, in addition to the actions performed by craft workers (Roberts and Ottaway, 2003, 127). Alloy choice is also a consideration in tool design. Durability and strength are concerns when creating bronze tools that will be used to fabricate bronze objects. To this end, a selection of tools were analysed using a portable X-Ray Fluorescence energy-dispersive analyser (pXRF) in order to determine if there were regional alloy preferences for tool manufacturing, and if the alloys used in tools were similar to those used for other contemporary bronze objects. The data collected was also compared to earlier published analyses (Chapter 4).

From this information, a series of databases were constructed, including data about the distribution and context of tools, the types of tools found, wear, comparison to contemporary tools from the continent, and possible modern equivalents (Chapter 5).

## METAL IN DEPOSITIONS

In Chapter 5 it will be shown that metalworking tools are predominantly found in hoards. Hoards are a collection of objects found in a discreet location. However further definition varies greatly depending on the period in which the hoard is deposited and the types of objects included. In England, the Portable Antiquities Scheme describes a hoard as:

> Prehistoric base-metal assemblages… from the same find. In this case,–the 'same find' means closed groups of objects including scatters of contemporary metal types which may reasonably be interpreted as having originally been in a closed group.
>
> The Treasure Act 1996 Code of Practice (Revised) Section II (ii)

In 1881 Evans defined those hoards that contained metalworking tools and stock as founders' hoards (Evans, 1881, 456-69). Early definitions described these hoards as caches of tools and supplies of itinerant metalsmiths, and were for one reason or another never recovered (Evans, 1881, Childe, 1930). Later interpretations of hoards suggested that they could have had a more ritual nature, as votive offerings or possibly the remains of a ceremony (Bradley, 1998). Tools can be highly symbolic and their presence can provide clues that might further define hoards. These symbolic associations can also be used to identify smiths. An example is the Greek god Hephaestus, who is easily recognised on red figure vase paintings because he is shown holding his hammer and tongs. On the continent, burials that include metalworking tools as grave goods are identified as smith burials (Budd and Taylor, 1995, 140). There are no known smith burials in Bronze Age Britain, and instead metalworking tools are most frequently found in hoards. This thesis examines hoards that contain metalsmithing tools often referred to as "founders' hoards" and considers their position within the conventional definitions of bronze hoards. The hoards selected for this thesis are differentiated because they contain metalworking tools, but as will be seen in Chapter 7, the elements that constitute the hoards and their condition indicate that event.

In modern context the word hoard has the implication of accumulation for the sake of accumulation, of senseless acquisition, or the pathological need to acquire as much as possible (Kaplan, 2007). While the archaeological term might be seen as neutral, there is often the risk of it being coloured by the modern connotations. Using the more specific term *founders' hoard* is also problematic because it has acquired its own terminological baggage (as discussed in Chapter 3). The term has accrued generations of interpretations, ranging from statements about caches of supplies made by itinerant metalsmiths (Childe 1930), accumulations of copper alloy objects that were discarded because they were superseded by iron tools and were no longer valuable (Burgess and Coombs 1979, v), or were interred as offerings to gods or supernatural beings (Bradley 1998; Brück 2001). In order to provide an impartial base for the exploration of the subject, rather than using the term *founders' hoards* a more neutral terminology has been adopted, and will be described as hoards or accumulations of metal that contain metalsmithing tools.

Chapter 3 explores hoards and the context of where metalworking tools are found, and how that might relate to the value of the objects in depositions. Chapter 5 examines the types of tools found in hoards along with spatial analyses in order to recognise regional trends for depositional practice.

## EXPERIMENTAL WORK

In order to understand how bronze metalworking tools function and their durability, the tools examined and analysed in museum collections were replicated for use in a series of experiments (Chapter 6). Working with these tools to create other metal objects provided a basis for organising the various processes the smith would perform in order to complete a metal object. In addition, the wear and other changes were then compared to the condition of the original tools examined in museum collections described in Chapters 4 and 5.

These combined methods provided a means of organising a metalsmithing toolkit and recognising those tools necessary for the production of the objects manufactured in the Bronze Age. By cross-referencing metal objects, tools, and the data gathered in this study from analysis and experiments, a system was developed for organising metalworking that will aid in recognising both tools that have been recovered, and those which are missing (Chapter 7). For this, a list of the minimum tools and materials that are required for the completion of a task has been established in order to give insight into the metalworking processes of the Bronze Age in Britain.

## CONCLUDING REMARKS: SMITHS AND THEIR TOOLS IN THE BRITISH BRONZE AGE

Archaeological studies of Bronze Age metalworking has, for the most part, concentrated on casting, smelting, and other pyrotechnical practices, while ignoring the more mechanical facets of the craft. Tools such as hammers, anvils, and chisels are barely noted in reports and are often assigned to a category of miscellaneous objects. By presenting a thematic study of a class of tools and their functions from the whole of the British Bronze Age, this thesis will provide a more grounded understanding of the craft of the metalworker during a defining period of British prehistory.

By approaching the study of metalworking tools from a holistic and functional approach that includes research and analysis, new insights can be gained into the craft of the Bronze Age metalworker.

# Chapter 2 THE SMITH IN MYTH AND ETHNOGRAPHY

*"Like any other things in this world, most of us will just become stories and those stories made us."*

*~ Jonathan Carroll*

## THE SMITH AS AN ARCHAEOLOGICAL SUBJECT

Myths and legends of metalsmiths are found in almost every culture. In some they are powerful beings, even gods (Robins 1953; Eliade 1956; Gillies 1981; Scott 1989). In some societies smiths trace their lineage back to the beginning of creation while the knowledge of the craft is passed from master to apprentice (Aremu 1987; Lahiri 1995; Marchand 2008). In this chapter the subject of the smith is explored both as a powerful mythic and historical figure. It will also examine how tools define smiths in that they are not only instruments to create objects, but are also important elements in the construction of a smith's identity.

By employing myths and ethnographic studies as resources we can begin to view various aspects of a smith's life: their associations with power and arcane knowledge, how knowledge was transmitted, the significance of the objects they made, and how smiths might have functioned as part of their communities. Topics such as these cannot be addressed through the examination of material culture alone, but can be enhanced using ethnographic studies of metalsmiths and how they practise their craft. It is important to keep in mind that myths and ethnography will not provide definitive answers to questions regarding smiths or the use of tools in prehistory, but they can provide us with diverse ideas of how we might approach questions of the transmission of knowledge, power, and the use of tools as symbols.

In earlier archaeological literature the metalworker was always assumed to be a male absorbed in the technology of invention. Metal technology was developed because *Man* somehow needed to create metal tools, and this came about through logical and progressive stages. However, rather than being brought about by predetermined necessities, another view is that the basic components from which technology develops are derived from aesthetic curiosity (Smith, 1981, 347).

> …critical stages have seemed to be more often irrational than logical. The mutant seeds of the most formal theories form in the mind of one individual, a mind shaped by experience that is more sensual than intellectual. Intellectual analysis can only follow discovery, and discovery makes more use of the aesthetic nature of the whole man than of his cerebral capacity
>
> (Smith, 1981, 344)

This change of viewpoint opens new avenues of interpretation where the smith is characterised as an artisan rather than a technician. This identity more closely resembles the examples presented in this chapter, where smiths are both innovative yet culturally defined, and are creators of objects that are invested with spirit. This spirit is not limited to the objects they create, but is also contained within the smith's tools, making them significant objects in their own right.

Today because most bronze is cast in modern foundries with gas or electric furnaces, ethnographic studies conducted in India and West Africa are an important resource. This is not only because the processes would be more closely related to that used in the Bronze Age, but also because, rather than occurring in a factory setting removed from the community, metallurgy is practised either within or in close proximity to the community where it would be seen and experienced as a part of daily life.

Many ethnographic studies of metalworking concentrate on iron smelting among groups in Africa or Southeast Asia (Childes and Killick, 1993, Gordon and Killick, 1993, Lahiri, 1995). While these studies can be useful, iron working is entirely different from non-ferrous metalworking. In most cultures iron smelting has its own traditions and taboos that are different than that of non-ferrous metalworking. The male symbolism of the shaft furnace and the process of removing the bloom, with its association of childbirth, are far different to melting metal in crucibles that are set into a furnace that can be dug into the ground (Gordon and Killick, 1993, 259, 265). Such distinctions are important to consider when using ethnographic material to characterise smiths who exclusively worked with non-ferrous metals.

Myths and legends also provide information about the early images of smiths and how they could have been regarded. Scott (1989) re-examined mythological texts in order to understand metalworking techniques as described in the original stories. He found that problems arose when the authors were unfamiliar with the processes, or described processes that they have not witnessed themselves. From these examinations Scott found that it was necessary to understand the need for smiths to work with sometimes arcane seeming material, such as in the Irish myth of *Da Derga's Hostel* where a magic spear is described, and that it must be quenched in noxious black liquids lest it kill of its own accord (Cross and Slover, 1935, 230). Such myths reflect experiments with sometimes unusual techniques described in medieval texts (Theophilus, 1979, 94-95). While these stories seem arcane to modern analytical views, they reflect knowledge of the craft encoded in stories where the jargon used in different eras often creates a barrier to understanding the smith's craft, and serves to keep the mechanics and practices of the craft secret. This is not only a problem found in interpreting myths, but also in historical documents in which the encoded information from myths is perpetuated as literal fact (Scott, 1989, 248, Childes, 1993, 325). An exception was Theophilus, who in the 12th century studied the arts intensively in order to accurately record activities in the workshop (Hawthorne and Smith, 1979, xxxii).

This chapter also draws on material primarily from the myths of Northern continental Europe, Ireland, and Britain, sources which can provide a back story presenting the earliest references of smiths and their craft. For this, the chapter will first examine the association between smithing and power, embodied in their ability to create objects, and how those objects are understood to have power in their own right. Because smithing has also been associated with arcane power, this chapter will also explore how smiths and their craft have been associated with rituals. Finally the chapter will consider the debate surrounding itinerancy and smiths. Because the only evidence we have of smiths in prehistory are their tools and metal objects they created, the material presented here establishes a foundation upon which we can examine the smith as an artisan, and as a person who had a defined social role. Through these studies, we can visualise the person who used the tools found in Bronze Age contexts, and how tools were used both as instruments for working metal and as symbols of the smith's identity and power.

## SMITHS AND POWER

> I invoke therefore all these forces to intervene between me and every
> fierce merciless force that may come upon my body and my soul:
> against incantations of false prophets
> against black laws of paganism
> against false laws of heresy
> against deceit of idolatry
> against spells of women and smiths and druids
> against all knowledge that is forbidden the human soul.
>
> *The Breastplate of St. Patrick (*trans. J.H. Bernard and R. Atkinson)

Smiths are depicted in art and stories as formidable beings, creating powerful, magical, and valuable objects. The craft is associated with mastery of the elements and is one of the few crafts practised by gods. Ethnographic literature connects smiths with shamanism, healing, and secret knowledge beyond that of working metal. While there are many variations, themes of power and occult knowledge run through the literature. Examples of the smith's power range from the making of magical objects to the creation or regeneration of life itself. Hephaestus was said to have constructed metal automatons to carry out menial tasks at the forge. He also moulded Pandora out of clay, cast her in gold, and then brought her to life (Robins, 1953, 41). In Greece, before Hephaestus, there were the Dactyls, creatures born of the earth mother Rhea, who were metalworkers, healers, magicians, and had knowledge of mathematics and writing (Kerényi, 1958, 74-5). In Norse mythology there was Sigurd, who was a smith, a poet, musician, and had the knowledge of carving runes (Robins, 1953, 128).

The divine smith was not restricted to male characters. In Ireland, Brigit was also seen as a goddess who had the power to wield fire and was associated with metalworking, in addition to being a healer and a poet (Gillies, 1981, 74).

In early Ireland smiths were held in high esteem, not only for their ability to produce valuable objects, but also because of their association with supernatural powers. Smiths who were considered masters of their craft, were given the status of *nemed* a term that was connoted with the sacred and allowed them to participate in public rituals. Benefits of their status included owning property, having a voice in the government, and participating in the rituals of the community (Gillies, 1981, 76-77). In

Irish mythology, Goibhniu, one of the smith gods, is associated with ritual feasting, and while Culann was a mortal smith, he was of high enough status that he could invite the king of Ulster and his retinue to his banquet (Gillies, 1981, 72, 76).

This power is also seen in ethnographic studies conducted in West Africa. Before European colonisation, Yoruba smiths enjoyed a high status. Their honour and lineage was sung by praise singers. Food, wives, and servants were provided by the village to celebrate the completion of successful casts. Rewards were given in the form of help to build a new house, or chiefs would award smiths land to found new settlements and slaves to work the land for them (Dark, 1973, 53, Aremu, 1987, 312).

This power derives in part from the smiths' knowledge and ability to transform raw metal into objects that could be either utilitarian or objects denoting prestige. The creation of these objects results in a cyclical relationship in which power is conferred upon the smith through the ability to manufacture these objects.

### *SMITHS CREATE OBJECTS OF POWER*

The smith is seen as the source of all craft. In a legend of King Solomon, a banquet was held for all the craftsmen who built his temple. The smith was not invited, but appeared anyway, dirty and covered in soot. When asked what part he held in building the temple, since he did not do carpentry or masonry, he answered that without the tools he made, the stone could not be dressed, nor the timber cut and carved. The smith was then invited to wash and sit at the right hand of Solomon (Robins, 1953, 73).

This idea of the smith as the one who provides the means for others' work is also addressed by Eliade (1956, 101). He points out that while the primary god possesses the thunderbolt or other objects of supremacy, it is the smith who manufactures these tools. An example is seen in the stories of Hephaestus. Unlike other gods, he worked with his hands and had his own workshop. His presence was begrudged, but he was accepted among the gods, possibly in admiration for his skills as an artisan. Presumably Zeus could not produce his own thunderbolts and so was dependent on Hephaestus, the only craftsman in the pantheon, and the only god who had the skill to make them.

The objects smiths created contain aspects of the smith's power and also represent the performance of metalworking in a complex relationship in which the biography of tools, objects, and the human agent are intertwined (Heidegger, 1962, Brück, 2005, 59, 2001b, 65, Pollard and Bray, 2007, Ingold, 2010, 94). This creates social bonds in which the object connects people both spatially and temporally where they "…become increasingly linked together by a sense of deeper hidden structures" (Hood, 2009, 234). Such objects can transcend their unexceptional character to become powerful symbols in themselves that prompt strong culturally embedded reactions (Hood, 2009, 47).

### *BECOMING A SMITH*

As the creator of powerful objects the metalsmith must maintain control of the knowledge of the craft. The transmission of knowledge must be carefully passed from one generation to the next, taught from master to apprentice in a lineage that extends back to the Bronze Age. Because of the craft's unknown and ancient origin, some cultures assign special origins to smiths, such as in the Book of Isaiah, where smiths have a special descent in that they were created by God:

> Behold, I have created the blacksmith, Who blows the coals in the fire, Who brings forth an instrument for his work; And I have created the spoiler to destroy.
>
> Isaiah 54: 16 The Bible, *New King James Version*

The Igbo smiths of Nigeria claim connections to origin myths of their people and so would travel with priests from village to village (Neaher, 1979, 355). In northeast Yorubaland, the Obo-Aiyengunle traditionally believe that all of their men are hereditary metalsmiths, although very few practise the craft (Aremu, 1987, 305). In India the caste of metalworkers is affiliated with royalty and religious tradition, because they are descendants of those who provided ritual vessels for temples (Lahiri, 1995, 122).

Eliade (1956, 81-2) described the Russian Yakut smiths as being 'masters of fire' who trace their lineage to Boshintoj, a smith god that came to earth to teach humans to work with metals. The children of Boshintoj became the ancestors of all the Yakut smiths, thus making them a race apart from other humans, endowed with occult knowledge and shamanic healing powers (Eliade, 1956, 83).

In Ireland, a tribe of gold and bronze smiths called the Cerdraige, were said to have been the descendants of a third century king of Munster and were ranked among the highest levels of artisans (Robins, 1953, 64). The name is derived from *Cerd* (smith) and *raige* (a collective suffix, translated as *folk*) The Cerdraige (smith-folk) and the Semonraige (rivet-folk) lived in West Cork and County Waterford, where ancient copper mines are also found. (Gillies, 1981, 79-81).

Craft practitioners become adept through the careful observation and imitation of the master's actions. These observations are stored and replayed by the apprentice. Beginning with the imagined image of the finished object, the actions can be manifested into reality in the final form of the object. Marchand (2008) identified this as embodied learning, in which discursive teaching is minimal and skill is gained through repeated exercises. Through this technique the apprentice learns to use tools as bodily extensions and haptic sensations become coordinated with visual and audio stimuli. Marchand takes this a step further and sees the object and the tools as an extension of the "craftsman's unfolding idea" where mastery of the craft is continually renewed through the sensations of the performance. Pink describes this as "knowing in practice" where learning is embodied in multisensory experiences while engaged with the material (2009, 34). Thus, it is not enough to imitate the actions of a master artisan. Apprentices must be able to assimilate and embody the skill in culturally appropriate ways, and then to develop their own, unique expression (Pink, 2009, 36).

The smith must learn instinctively how to pull, draw, or stretch the metal. Each hammer blow must be delivered with equal force so that the surface is even. Errors result in additional work to repair. The smith must also learn to hear and feel when the metal has too much tension; the ringing sound and the bounce of the hammer will tell the smith when it is time to anneal the metal before metal fatigue causes it to crack. When casting copper or bronze, the smith must watch for the flame to flicker green, indicating that the metal is molten and ready to pour. These signals are a result of external sensations to which the smith responds with skilled actions. This is described by Ingold as the *poetics of tool use* (Ingold, 2000, 415), where the performance becomes one of a feedback loop in which the smith senses changes in the metal, which then demands specific actions from the smith. As the smith develops greater skill this becomes a cycle in which problems encountered are solved as part of the actions to complete the object, and the on-going process of synthesising information appears to be instinctive. The ability to create objects comes through these acquisition of skills, which in turn through practice, develops the smith's dexterity and confidence (Connelly and Dalgleish, 1989, Sennett, 2008, 238, Valentine, 2011, 298). Such ingrained knowledge appears to the non-adept as something marvellous. The effect is that of someone who appears to be performing a ritual with measured actions, rhythm, with an almost prophetic vision of what the object will be before the process of manufacture has even commenced.

## Ritual and Metalsmiths

The skilful creation of objects is anchored in repeated practice such as carefully laying out tools before commencing work, or the rhythmic acts necessary for the object's completion. In modern contexts this would not necessarily constitute ritual practice, however, many ethnographic studies point to the ways in which religion and ritual are intertwined with cultural and vernacular activities, and that the world-view is not so clearly divided between religion and technology (Rasmussen, 1992, 125, Colwell-Chanthaphonh and Ferguson, 2010, 328).

In ethnographic examples, ritual can be seen to be carried out as a part of the process of making metal objects, or that the act of smithing can be a part of a larger ritual. Thus, smiths, metalsmithing, and the resulting objects can all be identified with ritual or religious practice. When ritual objects were to be cast in Benin, the Oba, the master metalsmith, sacrifices a rooster, a goat, and a cow in the location where the moulds would be placed. The workers then pray to Ogun (the god of the metalsmiths), to a spirit that represented their own personal destiny, to the deceased masters of their craft, and to Iguehae (the first brass-smith). On the day of casting, the sacrifices and prayers are repeated. Blacksmiths, who are considered inferior and are treated as servants, arrive only after the sacrifices are completed. Their task is to provide the charcoal and to pump the bellows. As soon as the metal is poured, they are sent home and not allowed to see the mould as it is broken open (Dark, 1973, 52).

Eliade (1956, 71 ff) discussed a translation of Babylonian rituals surrounding metalsmithing that is similar to the rituals conducted by the Benin Oba. These also include animal sacrifice; in addition, care was taken that fortunate days were chosen, and the area for the furnace was proscribed to strangers and unclean people.

Failed castings could be blamed on mechanical aspects such as quality of materials, a missed step in procedure, or human error. However, other factors such as sorcerous interference, or breaking of taboos were also serious considerations (Childes, 1993, 327).

Becoming a metalsmith is also a process that is accompanied by ritual. In north-eastern Yorubaland apprentices are chosen with the help of an *Ifa,* an oracle who determines a child's future occupation (Aremu, 1987, 311). Among the Awka in Nigeria, a ritual feast is held that elevates an apprentice to a master smith. As part of the ritual the initiate is given an Ótutù, a large hammer that not only symbolised his mastery, but also conferred the ability to set up a workshop and to take on apprentices (Neaher, 1979, 358).

Victor Turner created distinct categories for various spiritual practitioners and defined separate roles for priests and shamans. Priests are trained through learned traditions and provide an institutional function for the community that is connected with ceremony and temporal cycles. Shamans perform rites that might involve the community, but are more closely connected to healing rituals on a more individual basis, and are performed as needed (Turner, 1985, 148). Eliade also recognised a distinction where shamans are recruited based on physical or emotional differences, and powers are bestowed by otherworldly beings, or transmitted through inheritance (Eliade, 1964). With the limited information available, the Bronze Age smith could fit either of these definitions. However, while ethnographic evidence is valuable, it cannot be assumed that the examples available from modern contexts would apply directly to archaeological cases. Nevertheless, it is necessary to understand the various leadership roles undertaken in ritual activity in order to describe the roles of smiths within the community (Budd and Taylor, 1995, 139).

Budd and Taylor believed that Bronze Age smiths, like those in ethnographic studies, also held high-status positions either as secular or religious leaders. They saw the origins of this in the translations of the first metal objects that were less utilitarian and more ceremonial, to later functional objects that retained the aura of ritual use. Smiths became politically powerful figures through the creation of these objects in a process that appeared both magical and transformative (Budd and Taylor, 1995, 140).

### *SMITHS AS HEALERS*

Mythical smiths were also associated with healing. In the story of the Irish king Nuada, the king's arm was cut off during the battle of Mag Tured. Dian Cécht the healer and Credné the smith created a new arm out of silver for the king "with vitality in every finger and every joint of it" (Cross and Slover, 1935, 13). Gillies noted that even into historical times in Ireland and Scotland the smith was believed to be able to both cure and curse. Their power was such that according to the Irish Laws, smiths were exempt from liability if someone was injured at their workshop, unless it could be proved that the act was done with intentional malice (Gillies, 1981, 73).

In southern Nigeria, Igbo smiths have similar status to doctors, and the town is divided so that smiths, priest-doctors, and traders live in one half, while farmers live in the other (Neaher, 1979, 354). Smiths are connected with origin myths and at one time travelled with priests from village to village (Neaher, 1979, 355). The Obo smiths of northeast Yorubaland also practise traditional healing and enjoy the combined status of being both metalsmiths and doctors (Aremu, 1987, 312). They have the capacity to function as priests and have a spiritual status above that of others in the community. They also have have the potential to be considered sorcerers in their own right (Neaher, 1979, 361, Childes, 1993, 330).

### *FEAR OF SMITHS*

The mythological and ethnographic examples presented here demonstrate that smiths can be believed to have power over life and death, in addition to bring about curses, control spirits, conduct rituals, and manufacture charms. The smith is also able to create objects that confer wealth and prestige. Members of the community are dependent on the metalsmith to manufacture tools and prestige objects (Rasmussen, 1992, 107ff, Falchetti, 2003, 347). This dependence on objects made with secret knowledge engenders fear, since controlling aspects of both ritual and daily life results in a cultural ambiguity in which power can be exploited (Rasmussen, 1992, 109). The smiths' power as sorcerers and their connection with the spirit world can overshadow the power of the chieftain or local ruler, resulting in tensions with secular political leaders. To ease this tension, in some societies smiths live in an area segregated from the rest of the village, which is seen as a means of restricting their power and status (Childes, 1993, 330).

The manifestation of the fear of the smith's power is illustrated by the story of Wayland, or Volund, as he is known on the Continent. Wayland is attributed with making magic rings and weapons, including Beowulf's armour and Charlemagne's sword. Because of his power to make powerful objects, the King of Sweden first commissioned Wayland to work for him, but then grew to fear the smith's powers and became afraid that he would make similar objects for others. The King ordered Wayland to be hamstrung, crippling him, and then imprisoned him on an island where he would continue to make magical objects solely for the king. Wayland escaped by creating a set of wings, an act compared to that of Daedalus, and also similar to stories of northern European shamanic flight (Robins, 1953, 47-8).

This fear is also seen in the scorn for Traveller tinsmiths. While they are usually considered as disreputable people, they still retain an aura of romanticised mystery, power, and forgotten or archaic knowledge (Robins, 1953, 122, Rehfisch, 1975). Various legends connect their transiency to the smith who forged the nails for the crucifixion and as a result his descendants were cursed and despised wherever they travelled (Robins, 1953, 118-121).

So far we have examined the smith as a person of power, both as someone who created powerful objects, or as someone possessing arcane knowledge. The myths and legends portray the smith as someone who worked within a community, be that of humans or gods. The ethnographic studies examined in this chapter also place the smith in a community with strong social ties. However there has been a long archaeological debate about how smiths were a part of communities based upon the distribution of metal objects and metalworking evidence found in hoards. The following sections address this debate using ethnographic examples to examine different ways in which itinerancy can be defined, in addition to the various ways in which smiths serve communities.

## THE ITINERANT SMITH

Since the beginning of the study of archaeometallurgy there has been debate about whether smiths were itinerant or sedentary. The focus of this question has always centred on the location of where the work was performed. Rather than start there, it would be important to explore what is meant by the word 'itinerant'. How is itinerancy defined? Is it an individual who is unsettled and travels unceasingly? Is it someone who travels on regular rounds from village to village, carrying all the necessary tools and supplies? Is it someone who has multiple places of residence? Or is it someone who travels a distance for supplies, and then returns to the homeland to manufacture objects with new materials and ideas?

Childe, basing his work on the idea that Bronze Age societies functioned within the context of a market society, argued that Bronze Age villages were small and could not support a full-time smith. Smiths would necessarily be required to travel in order to have a sufficient market base for their goods. He believed that this, combined with the often remote locations of founders' hoards, provided evidence that smiths were itinerant (Childe, 1958, 168). The resulting vision was a detribalised smith who lived "outside the bondage of tribal custom" (Childe, 1930, 10).

There are ethnographic cases of itinerant smiths. Nancy Neaher writes about the Igbo tribe in West Africa, where metalsmiths have a long tradition of itinerancy (Neaher, 1979). However, this is not Childe's carefree, socially unfettered smith who lived without the confines of social restriction. Instead, the smiths are subject to complex social structures. Rather than no fixed residence, Igbo smiths, who work in both ferrous and non-ferrous metals, have a home village where they must return on a regular basis. The situation is structured so that half of the village metalworkers will be away at any given time. When one smith returns, another sets out (Neaher, 1979, 356). The timing and destinations are also structured so that smiths must return by a particular festival date or risk penalties. In addition, smiths might have another wife and family in the village where they travel. In some cases the presence of Igbo smiths replaced local metal workers, and these regions became dependent upon the foreign Igbo smiths (Neaher, 1979, 355). However, despite constant travelling and close relationships with other regions, the smith is identified with his home village (Neaher, 1979, 357). In addition, groups of Igbo smiths working away from their home village meet regularly as a guild to discuss business affairs and to ensure regulation of manufacture and trade (Neaher, 1979, 357). This guild also enabled smiths to control the exchange of elite goods, dictate changes in fashions and styles, as well as discuss news of other regions (Neaher, 1979, 363).

There are also accounts of Yoruba brass casters who were invited to travel to other towns and cast objects there. However, after the casting is completed, the Yoruba smiths return home. In addition, while Yoruba smiths from Obo, the home-base for the Yoruba smiths, can relocate to neighbouring towns to practise their craft, smiths from other towns do not travel to work in Obo (Aremu, 1987, 306, 313). These systems demonstrate complex relationships in which social codes dictate the times of travel and destinations (Neaher, 1979, 357).

## THE SEDENTARY SMITH

Rowlands (1972, 214) describes other ethnographic examples of smiths in both Yorubaland and other areas of West Africa who might supply the metalwork for multiple villages, but who still live and work within a settlement. He also argued that the regional distribution of metal in the Bronze Age indicated that the industrial organisation of metallurgy was practised on a local level in individual settlements (Rowlands, 1976, 163). A modern example can be seen in the organisation of the brass casters of Benin City. Before the craft was organised into a school in 1927, the brass-smiths worked in guilds established within specific wards of the city. The artisans would work there all day, and then return to their home in another part of the city where they worked on their own projects. A senior artist, the Oba, controlled production and could require the artisans to stay in the ward if they were needed to continue work on an important object (Dark, 1973, 45).

Various archaeological theories support the concept of sedentary smiths. Budd and Taylor not only rejected the idea of itinerancy, but suggested that metalsmithing might not even be a gendered profession, and metalworking could have been practised by specialist family groups (Budd and Taylor, 1995, 138). Small settlements that were comprised of extended families would have had all able members participating in routine activities, including metalworking (Brück, 2008a, 254, 258, Mulville, 2008, 234). In Yorubaland smiths work as family groups, with children and wives helping out with tasks such as grinding charcoal, pumping bellows, and caring for tools (Aremu, 1987, 311). However, smiths did not apprentice their own sons. This was done in order for them to study under others and "acquire more wisdom" (Aremu, 1987, 306), or to prevent situations where fathers would treat sons preferentially (Neaher, 1979, 357).

An example of a more structured metalsmithing community is seen in the smiths of Benin City, who were organised into guilds that had a hierarchy that determined the division of labour. The most important commissions went to the Oba and less important work would be handed to the chief metalsmiths and their groups. While a chief might not be the most competent metalsmith, another member of his group might be. However, work was shared through the group so that every smith had an equal opportunity to lead a project (Dark, 1973, 51).

An archaeological theory of sedentism is provided by Pearce, who wrote that the Late Bronze Age smiths who worked in larger settlements were specialised and worked under the patronage of local chiefs. The metalworkers who made tools would be different people than weapon smiths or those who made ornaments (Pearce, 1983a, 231, 233). This specialisation would be tied to the size of the settlement, since a larger community is required to support multiple specialised workshops. In ethnographic studies it was found that settlements with a population of over 50 people tend to have members who are craft specialists (Orme, 1981, 110).

## THE ENVALUED SMITH

This chapter began with a quote about people becoming stories and continued with stories and myths of smiths that not only included smith-craft, but also ranked them as healers, shamans, and priests. The myths described in this chapter place smiths among the gods, where few other craft workers are represented. Even as mortals, smiths were accorded prestige and power. The legends and ethnographic studies record their skills as master artisans, some of whom claimed descent from these gods, or having a special creation that was different from that of other members of their communities. In a sense this is true, since the secret knowledge of creating metal objects has been passed down from master to apprentice in an unbroken lineage that extends back to the first smiths of the Bronze Age. This idea of lineage was expressed by Diderot when he stated that "It is handicraft which makes the artist, and it is not in Books that one can learn to manipulate" (Diderot "Prospectus,"Pannabecker, 1994, xl).

The myths and stories speak of the power of the metalsmith to create powerful and sometimes magical objects. These stories described the smith's skills and occult knowledge, and how the process of smithing often appeared magical. The wonderful pieces made by the smith gods could provide sustenance, inspiration, and grant power over life and death; and those made by mortal smiths have been associated with healing and occult power. These same qualities are imbued in the tools and the objects made by mortal smiths. The tools of the smith, the same as the tools found in Bronze Age depositions, were the instruments through which the smith manipulated raw materials and transformed them into objects that could be both utilitarian and symbolic. In the stories the essence of the smith is imbued in their tools and the objects they created.

The following chapter will explore the significance of tools and materials used in metalsmithing. The chapter will explain how value is socially constructed and the ways in which this can be interpreted in archaeology. Chapter 3, combined with this chapter, will establish a theoretical framework that will complement and provide support for interpreting the data that will be presented in Chapters 4 and 5.

The understanding the social significance of smiths and their tools, combined with contextual data, typologies, and analysis will provide a more comprehensive basis for interpreting metalsmithing assemblages that goes beyond interpretations that rely entirely upon metallographic or typological analysis. Through this a more complete understanding of metalsmithing in the British Bronze Age will emerge.

# Chapter 3 Valuing metal craft: The role of tools and materials

> *Through mastery of the operation of tools and of the techniques their use allows, the craftsperson "speaks" to the materials, and through his or her creation, communicates to others.*
>
> *Untracht 1985, 27*

From the beginning of archaeological study, metals have held a prominent status among materials. They became a focus for antiquarian authors, such as Mahudel, Lubbock, and Thomsen who used them as part of an organisational framework for prehistory as was seen in Chapter 1. The resulting Three Age System of Stone, Bronze, and Iron, gave metals the defining role in establishing how we organize prehistory.

Later Childe positioned metals as a significant factor in identifying social complexity. Because metals are durable they form a major part of the archaeological record and have been used to examine changes in society, trade relations, and class structure. More modern approaches explore the processes of how metal was valued both within economic and ritual spheres, as well as being an indicator of personal or social identity (Rowlands, 1993, Dissanayake, 1994, 100, Deverenski and Sørensen, 2002, 117, Howes, 2003, 225, Pink, 2009, 38, Thornton and Roberts, 2009).

Metal objects and technology do play a substantial role in prehistory. They have qualities, such as the ones described in this chapter, which set them apart from other materials. These qualities were valued enough to confer a special status on the objects that made them appropriate to be interred with the dead, sacrificed to the gods, and traded to distant lands. Because we do not know the basis for values in the past, we must make inferences built on the available evidence, such as context, rarity, or workmanship. The interpretation of the past is mutable and even the "material identity" of a bronze axe can be transformed from an ordinary tool to a ritual object depending on the judgement of the observer, or a reinterpretation of the context in which it was found (Holtdorf, 2002, 55).

In the previous chapter we saw how the smiths were powerful beings and that their tools and the objects they made were associated with that power. From the initiatory hammers given to Awka smiths to mythical weapons, objects of metal have the potential to be valued and highly symbolic. Even today metals are used to express values: we speak of "gold standards" and awards are given out with rankings of gold, silver, and bronze.

This chapter will explore the various ways in which value is assigned to tools and metal objects through their intrinsic properties, their availability, adaptability, and their use as signs of prestige. This will establish a framework for addressing issues of the value and power of metalworking tools based on the properties of metal.

However, before embarking on the exploration of the processes of creating value, this chapter will explore the terminology by which processes are explained. Tools and materials are placed within a context of activities that surround the creation of metal objects. As will be shown in this chapter, metalworking is not often as straightforward as it would at first appear, and that a model such as *chaîne opératoire* works well for describing some processes, but becomes problematical when describing metalworking processes.

## *CHAÎNE OPÉRATOIRE* AND THE PROCESS OF CREATING METAL OBJECTS

The term *chaîne opératoire* was first used in conjunction with the processes involved in knapping flint. Leroi-Gourhan described the steps in which the raw material is procured, shaped, and treated until the final object is completed. This was a "series of technological operations which transforms a raw material into a useable product" with attention paid to the sequential steps of the manufacturing process (Cresswell in Martinón-Torres 2002). Rather than focussing on the object, *chaîne opératoire* concentrates on the sequence of manufacture (Martinón-Torres, 2002, 31). It became a useful means to understand the process of manufacture, and how those processes are connected to the social and symbolic aspects of technology.

Lemonnier (1992) expanded the use of the model so that it could be used for other creative technologies, and since then has been used for exploring technological choice in as diverse practices as lithics, traps, dwellings, pottery, textile manufacture, and the creation of Palaeolithic clay figures (Vidale et al. in Bleed, 2001, 106, Martinón-Torres, 2002, 34, Kreiter et al., 2014). *Chaîne opératoire* is used in the archaeological literature by authors such as Rosen and Roux (2009), and Berranger and Fluzin (2012) to describe metalworking processes and production. It was further developed to explore technological sequences that were rooted in behaviour, organisation of activities, and sequential thinking (Bleed 2001, 108).

However, anthropologist Robert Aunger avoided the term and concentrated on defining the process of manufacturing tools as types of production, or as sequences in an object's life history (2010 765, 771). The analogy of a chain is limiting: the original purpose of *chaîne opératoire* was to explain the sequence of flint knapping, a reductive process that is linear in its performance. One step follows another, like the links in a chain, from the choosing the initial cobble to the finished object. In addition it is a process in which only one object is made at a time. While Bleed (2001, 119) felt that the sequencing model could be applied to other technologies, Lechtmann (see Bleed 2001 p. 119) recognised the difficulty in identifying clear sequences in metalworking. Metalworking provides a challenge to *chaîne operatoire*, and rather than the analogy of a chain in which every link connects solidly to the next one in a linear sequence. Bleed proposed a dendritic pattern where production sequences could be subdivided into distinct tasks. Instead of a chain, the processes of metal production could be analogised as a river with multiple tributaries which flow, combine, and can later divide into multiple streams or flow into a single body of water. As will be seen in the example in this chapter, the metals that make up an alloy can have multiple origins, all of which flow together and combine to make a bronze dagger. Other streams can contribute to the processes in the form of sources that could include clay for moulds and crucibles, or the manufacture of tools for forming and shaping other metal objects. These processes then continue with the various ways in which the final object might take shape, such as an axe, a sheet metal cauldron, or as a tool that could be used to make more metal objects. In Chapter 7 a system for understanding Bronze Age metalsmithing practices is proposed. It will be seen when using this system, that the process of metalworking is not a linear process, but is performed at times in cycles. Just as a river will have pools in which the water eddies in loops, the smith will work in repeating sequences: when forging sheet metal, the metal will harden and needs annealing, annealing returns the metal to a softer state, so that the smith can continue working until the metal hardens again. This can also be seen on a larger scale with the ability of metals to be re-melted and recycled. This more fluid definition of the processes provides a more appropriate analogy for metalworking.

## THE PROCESS OF ENVALUATION

In the town hall of Modena, in Northern Italy, there is a rather ordinary wooden bucket surrounded by baroque splendour. The ornately decorated room is empty except for a ring of chairs arranged as if for veneration of a bucket enshrined in a glass case outfitted with a modern electronic security system. This bucket looks like any other old oak bucket that would have hung at a town well, and indeed it is no different than any other of its kind, except that it is *La Secchia Rapita*, "the Stolen Bucket" a trophy of Modena's victory in a series of battles fought against Bologna in 1325 (**Fig. 3.1**). There are rumours in Bologna that this is not even the real bucket, and that the Modenese substituted another ordinary bucket to preserve the memory of a war fought 700 years ago. The events of the battles of the bucket were commemorated in a mock epic poem, and the bucket itself is an icon featured on postcards and souvenirs. Materially there is nothing unusual about this bucket, but it has accrued meaning and value through these historical events, and is given treatment equal to that of any great work of art in an Italian museum.

**Figure 3.1 La Secchia Rapita**

In the telling its story we can understand how *La Secchia Rapita* came to be valued and the meaning behind that value. But should we have found this bucket in an archaeological context, what would we make of it? How can we explore the processes by which objects are transformed from the mundane to an elevated status in antiquity? The key lies in understanding the processes by which envaluation takes place.

To begin, we need a clear understanding of how meaning and value are defined that can be applied to a world far different than our own. In our modern world value is usually characterised numerically in a monetary system. We almost instinctively know the relative value of most objects in our lives. There are few objects we own that have not been obtained through purchases, and even those objects given as gifts were likely to have been purchased by another. Even objects that have sentimental value can have a monetary value assigned for insurance purposes. But once we step out of this system, how can we understand how value is constructed and assigned to objects? As seen above with *la Secchia Rapita*, value can issue from an object's history or symbolic importance. By examining different theories of envaluation, a framework can be created whereby we can attempt to understand how meaning and value are assigned to objects.

## How objects gain power

In early non-capitalist societies, surplus wealth could not be invested and instead a network of social indebtedness, interdependence, and support created prestige as the goal of investment. In this light, valued objects are less of a form of proto-money than they are chits in complex exchanges designed to elevate one's prestige (e.g. Mauss, 1990, Brück, 2006a, 75).

However a debate surrounds how objects in exchange are viewed. Authors such as Gregory (1982), Champion *et al.*(1984), and Kopytoff (1986), describe objects that are solely commodities. Mauss (1990), Strathern (1988), and later Brück (2006a) wrote that in early societies these objects were not commodities, but were extensions of the self and part of one's identity. Thus when an exchange is enacted, it is more than an object changing ownership. A social relationship is created in which a portion of those persons who were associated with the object's biography (the creator and previous possessors) has become a part of that object (Mauss, 1990, Brück, 2006a, 76). Mauss describes a system of exchange in Maori tradition in which the spirit of an object, *hau*, continues to have a connection to all those who have ever possessed the object (Mauss, 1990, 11). Sahlins elaborated on this, further defining the meaning of *hau*, to understand that it begins as the spirit of the creative act, and that the chain of exchange obligates the recipient to extend and recompense the previous owner(s), and how the *hau* will eventually return to the object's creator (Sahlins, 1972, 168). In modern psychology, this phenomenon is identified as *essentialism* an "invisible property that inhabits individuals but also [has the ability] to transfer that property to their objects" (Hood, 2009, 39). This way of thinking is not so far removed from modern society when one considers the significance of heirlooms, the value of antiques, or the importance attached to objects formerly owned by celebrities.

The idea of an object representing interpersonal relationships, or the physical embodiment of the relation was explored in ethnographic work by Broch-Due in studies of the Turkana of East Africa (1993), and Strathern with the Hagen people of Melanesia (1988). These studies examined the concept of people as pluralities in which objects represented not only the relationships between community members, but also were part of their persons (Broch-Due, 1993, 54-55, Strathern, 1988, 219). This phenomenon, *enchainment*, is a kind of social relationship in which members of a community are 'multiply constituted' (Strathern, 1988, 165). However, Strathern saw enchainment as going beyond the traditional ceremonial exchanges within kin-groups and communities to include barter and market transactions. The Hagen people view an object as the manifestation of interpersonal relationships where an object does not have a single creator, but instead is the product of an artisan working within the "context of multiple social relations with others" (Strathern, 1988, 164). Thus the creation of objects is the embodiment of social relationships and through exchange an object can expand beyond the original mutual connections and extends the relationships (Strathern, 1988, 161, 219-220).

Building on the ethnographic work of Mauss and combined with studies of economics and early exchange systems (Earle and Ericson, 1977), Needham described an *exchange effect,* in which he described shifts in an object's ownership and how that could affect the social status of the owner, especially if the object went from one social group to another. This creates a *social distance* where different values and symbolic meaning can be attached to the object (1993, 163). This is similar to Helms' view, who wrote that exotic objects have qualities that link them to their place of origin, associating their owner with the "mysterious, exotic, and powerful" (Helms, 1993, 48). Their possession and display demonstrate that the owner of these objects has ties to distant places

(Aremu 1987, 308), and the act of acquisition "conveys and expresses prestige" (Helms, 1993, 101).

Strathern, Needham, and Helms all acknowledged that the active agents (creators and owners) in an object's biography would continue to be a part of that object whether or not they were personally known to the current owner. The subsequent owners of a metal object would have a physical reminder of connections to the smith through the possession of the object. This recognises both the skill of the smith and the smith as a creator. Ethnographic examples of this are seen in Wiener's study of Trobriand Islanders (1992) where objects became inalienable possessions that retained permanent ties with previous owners. Brück later described this as an *inalienable nature*, in which the object becomes a "relational entity" through the interconnectedness of objects and humans (Brück, 2006a, 89). Here the power rests in the object rather than in an elite figure who owns prestigious objects (Weiner, 1992, 42, 52, Brück, 2006a, 93). Thus the smith could be considered the creator of that entity and the body in which the creative spirit originates.

## *OBJECTS OF POWER*

The powerful objects made by smiths have been equated with life, death, and regeneration. In the Kalevala the magician/artist smith Ilmarinen, claimed to have created the vault of heaven, and forged the miraculous object called the Sampo. The Sampo is never described or defined, but is equated with the creation of the world and the regulation of ploughing and sowing. Other interpretations describe it as a source of abundance, or an object that grants arcane wisdom and power through this knowledge (Pentikäinen and Poom, 1999, 33, 152, Scott, 1989).

In West Africa metal objects have power associated with transformative events in life. Women in Togo wear iron jewellery for naming ceremonies, while copper is worn for events associated with fertility such as births and first menses. Ceremonial objects made of metal, including spears and anvils, are part of rituals in which a tribal leader is invested and transformed from a human into a divine being (Childes, 1993, 332).

In the Irish *Book of Invasions*, the smith god Credné is associated with casting and goldwork, and Goibhniu is described as working at the forge, which could imply bronze sheet metal work rather than specifically blacksmithing. He is credited with the creation of shields and cauldrons, in addition to hammering the blades of swords and spears to harden and sharpen them. The objects that these god-smiths made - spears with unerring accuracy that deliver certain death, and the cauldron that restores life to those killed in battle - enabled the Tuatha De Dannan to win the Second Battle of Mag Tuired over their enemies (Cross and Slover, 1935, 40, Gillies, 1981, 72).

Cauldrons in the myths of Ireland and Wales have similar qualities. In Ireland there is the Cauldron of the Dagda which provided unlimited quantities of food (Cross and Slover, 1935, 12). In Wales there is the story of the Cauldron of Regeneration made by the giant Llassar Llaegsyfnewis, in which slain warriors were immersed and then emerged whole and capable of fighting again (Ellis, 1999, 329). In another Welsh story, the boy Gwion Bach, who would later become the poet Taliesin, gains shamanic abilities of physical transformation and prophecy after tasting three drops that boiled over from the cauldron of inspiration (Guest, 1877, 471 ff). These cauldrons of extraordinary power that had attributes associated with nourishment, inspiration, life and death, and the cosmos would later become associated with the myths surrounding the Holy Grail, thus regenerating the myth for a new culture (Pentikäinen and Poom, 1999, 23).

## Agency, tools, and value

Humans live in a world in which the materials play an active role in the creation of social relations. Objects exert an influence that can comfort, intimidate, or signal social status. They can identify someone as a member of a particular group or as a stranger, and can designate personal identity. However, in order to project particular values, these objects must possess socially recognised significance. The symbols become deeply rooted and “the individual cannot choose not to think and act through them” (Thornton and Roberts, 2009, 183). They become intercessors for humans and their world, drawing out and directing responses (Robb, 1998, 335). In this interactive state, objects themselves have even been thought to become active agents in human relationships (Knappett, 2002).

However, while Knappett considered objects to have a considerable influence on humans, he could be criticised for assigning too much authority to objects, and comes close to anthropomorphising them (Knappett 2002). Gosden (2001) felt that giving objects such an active role gives them a status similar to that of humans, while Gell regarded objects as secondary agents that function in the creation and maintenance of social relations. Although these objects do not act with intent, they are instead vehicles for agency (Gell, 1988, 20). Both Gell and Brück point out the tendency for humans to anthropomorphise significant objects (Gell, 1988, 17, Brück, 1999a, Knappett, 2002, 100, 2006a, 75). Instead of anthropomorphism, objects such as tools can be understood to function as prosthetic extensions of human hands and fingers (Marchand, 2008). This is especially relevant in metalworking, where it has been noted that metalsmiths cannot practise their craft without the use of tools. Tools make humans more versatile and less vulnerable. A hammer magnifies the force and action of the arm and hand. Tongs or leather gloves enable a human hand to be able to pick up objects that would otherwise burn flesh. In this way the tool is the bond between the metalsmith and the object being created (Scarry, 1987, 176, 284, 315) and aids in the manifestation of the smith's intention (Ingold, 2000, 414). However, the ease of use that comes through skilled practice gives the impression of tools having anthropomorphic qualities. Eliade and Helms both cite several ethnographic studies in which tools are assigned magical and human-like characteristics to the point that it appears as if the tools are actively doing the work, and the human is almost a passive facilitator in the process of creation. As a result, these magical tools then have the power to confer prestige on those who use them skilfully (Eliade, 1956, 29, Helms, 1993, 21-22). While tools can have powerful influences on humans, it is the human agent that ultimately decides their role in creating and manipulating objects (Gosden, 2001, 164). The tool facilitates the connection between the mind and the object in order for the object to be brought into being (Untracht, 1968, 27, Sennett, 2008, 213).

This connection of tool-user-object describes a mental process; however tools also have a physical effect in that they mould their user. While they are not animate, it can be seen that they do exert influence on humans who interact with them (McLuhan, 1994, 139). Humans, in order to practice a craft, must design and make the tools, and in the process of creating an object using these tools, they must also adapt to the tools. This can easily be seen in the design of a chasing hammer handle. Rather than a straight piece of wood, the design of the handle has evolved to have a flattened bulbous end. The design allows for the handle to fit the palm perfectly and to be gripped loosely. The action of hammering is performed by squeezing the lower three fingers, causing the hammer handle to bounce against the palm. The elbow is relaxed and motionless, and there is minimal movement in the wrist. The design is ergonomic and allows the smith to work for extended periods without fatigue or cramping. However, the hand will develop callouses and strengthened fingers as a result of making metal objects with this tool. The development of the design in the hammer results in changes to the smith in the process of creating metal objects. This was described by Ingold as a transformative relationship in which tools, humans and materials are in a reciprocal cycle of making each other (Ingold, 2006, 10).

It is through understanding the construction of these dynamic relationships that the process of envaluation can begin to be understood. Ultimately value and agency can be considered moving in parallel while accepting that each is incorporated in the other. They exist as a vibrant interplay between time, space, material, and history (Robb, 1998, 333, Preucel and Bauer, 2001, 87).

In the following sections a framework is outlined that seeks to describe the various aspects through which metal and metal objects become envalued. These aspects include ideas of history and memory, and how factors such as origins, traditions, and context, come to bear on the assignment of value. However, none of these categories is exclusive of others. While performance creates value, it is also dependent on the skills and knowledge of experienced metalsmiths, or the sensual experience of working metal. Fine craftsmanship is also valued, but here too, the knowledge of metalworking is an essential factor in the creation of prestige objects, which also is tied to valued traditions and history.

## The visual value of metal

While we as modern observers cannot fully comprehend the value schemes of prehistoric peoples, we do have the same ability to physically experience objects using similar senses as people in antiquity. By examining objects, observing their colours, texture, weight and other physical properties, we gain some understanding of the possibilities of how value is conferred upon objects.

Berlin and Kay (1969) outlined a universal evolutionary model for the social construction of colour terms. Beginning with black and white, the third colour to be incorporated is red. The next two colours of cultural importance are either yellow or green. Wierbicka also outlined a constant regarding universal colours in the natural world in which white is equated with day, black with night, yellow with the sun, red with fire, and green with vegetation (Chapman, 2002, 51).

While metallic colours can be related to normal spectral colours, they have a quality that sets them outside the range of normal colours. We speak of a metallic sheen and describe objects that are silver or gold coloured. These objects are not a light grey or ochre colour, but are invested with a quality described as "metallic" that is outside the normal range of colours. The colours of metal are almost part of the normal colour spectrum, but their lustre and metallic qualities set them apart. While white, red and yellow are all part of the physical world, the metallic colours of silver, copper and gold represent qualities beyond the physical colours to represent the metaphysical (Keates, 2002, 110, Jones and MacGregor, 2002, 9, Cooney, 2002).

Metals also have the ability to redirect light, both as a mirror reflecting an image or in the action of producing a flash of light. In some societies brightness is symbolic of power (Jones and Bradley, 1999, 113). In the case of polished metals, these visual cues would indicate desirable qualities that would form the basis for constructing value in a class of artefacts.

Metal alloys can also be adjusted to create a range of colours. Metallurgical knowledge enabled new alloy recipes that could be used to alter the colour and appearance of metal objects. The addition of arsenic to bronze gives a more silvery colour than that of a tin bronze (Keates, 2002, 111), and the addition of antimony results in a dark grey bronze that resembles haematite (Craddock, 1995, 291). Colour could be controlled to the extent that a bronze alloyed with more than 15% tin reduced the red colour, and percentages of tin over 18% reduced the yellow chroma to produce a more silvery colour (Fang, 2011, 54-57).

## Performance and the construction of value

The act of creating an object is in itself a performance and also provides an opportunity for the creation of value. Skilled craftwork relies on the ability of a knowledgeable actor working with appropriate materials and using techniques that draw upon the experienced movements of artisans exercising their craft (Barrett, 2000, 61). These performances represent intersections in a network that combines skills and knowledge, stories and memories that all contribute to the development of value within an object (Gell 1998, 222).

The processes necessary to transform ore to metal to a finished object set metals apart from other materials. Its ductility, its ability to be cast and recycled are properties not found in other materials available in the Bronze Age. While this does not necessarily make metals superior to other materials, the processes in their creation necessitated dedicated skills and technology. When pouring molten bronze or forging sheet metal, the medium wields as much influence on the body of the smith as the smith does on the metal. Bodily movements must be learned and the work executed according to the demands of the medium (Ingold, 2004, 57; Sennett, 2008; Marchand, 2008; Pink, 2009). While this is true of every activity from basket weaving to grinding grain, metal working demands attention, not only from those who are actively engaged in the process, but also from those who are within the area. The ringing of a hammer on metal will be heard throughout the village and the smith's ability to control fire and use tools as if they were bodily extensions creates a spectacle that approaches the supernatural (Eliade, 1956, 79). Onlookers are able to see metal transformed from one state to another, while the smith takes the object from one step to the next in a seamless performance. Almost everyone in a village environment is a participant, either actively as part of the metalworking process, or tangentially such as those who would provide support, materials, or food for the smiths. There are also passive participants who are engaged with the process: those who hear the constant rhythmic sounds of hammering and bellowing, or endure the smells of the casting or smelting processes. The entire community would be aware of the smiths performing their tasks. This performance comes through continued practice based on knowledge passed from master to apprentice in a process that is largely based on non-discursive learning.

## Valuing knowledge

In understanding the ways in which knowledge contributes to envaluation, it should be understood that knowledge draws on both memory and physical action. The metal worker must learn the craft, both through training and practise. The learning process is participatory and constantly in flux (Sennett, 2008; Marchand, 2008; Pink, 2009). . It is necessary for potential smiths to understand metallic properties such as melting points, how different metals interact in the process of alloying, or the tensile properties of different metals and alloys. The practical knowledge cannot be explained, but has to be experienced by the apprentice smith.

Unlike most crafts, the processes of metalsmithing are not easily observed; smiths need to understand metal by touch and hearing as much, or even more than by sight. For example, when forging sheet metal, the smith will know that the metal requires annealing because the hammer springs back rather than connecting with the metal, and that it will make a different ringing sound as it strikes.

Likewise metalsmiths need to know how their different tools function and modify them if necessary. For instance, if metal is struck by a hammer with a flat face, the force of the blow will cause the metal to shift equally in all directions. This type of hammer is useful for flattening or smoothing sheet metal, but will frustrate the smith attempting to forge an ingot into sheet metal. However, by modifying the face of the hammer into a wedge shape, the blow will cause the metal to shift in two directions, and by directing the blow, the smith can pull the metal so that it stretches in only one direction, thereby controlling the process of forging in order to create a desired shape (**Fig. 3.2**). This is one example of how tools are adapted for specific tasks. Over time the smith will acquire a range of tools designed to accomplish specific tasks.

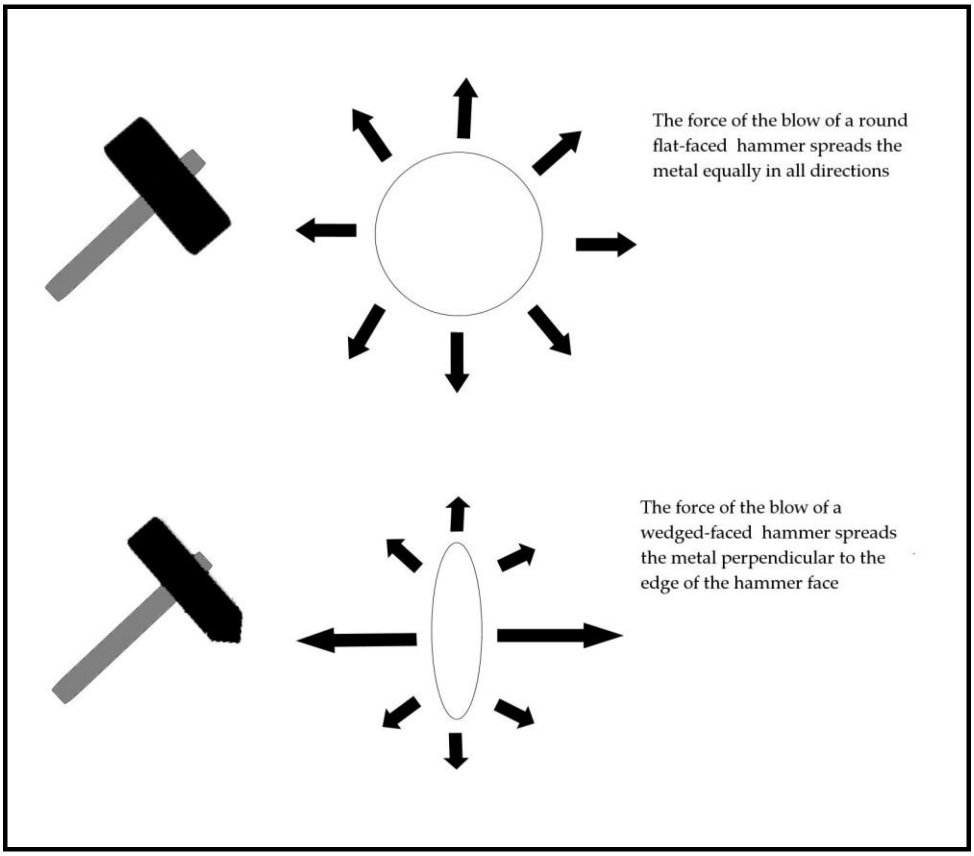



**Figure 3.2 How the shape of a hammer face affects the direction of metal deformation**

Through the knowledge and experience of metalworking processes and the functions of tools, smiths are able to create objects that would be difficult or impossible for the person lacking metalsmithing knowledge to achieve. Over time this knowledge becomes embodied and the series of tasks becomes a seamless performance in which a finished object becomes a manifestation of the smith's skill. This is a circular process where the smith's original experience is based upon creating previous objects. That object then becomes an active agent providing an aides-mémoires of the smith's past physical actions, and embodiment of past sensory experience (Kopytoff, 1986, 81, Rowlands, 1993, 142, 144, Pink, 2009, 34).

## The value of exotic origins

The source of materials implies a location in time and space that can be either known or ambiguous. These can be manipulated, obscured, or falsified. While some native metals have a metallic appearance that makes them easily identifiable, many ores do not resemble the refined metal. This meant that specialised knowledge was needed to recognize metal sources, and such knowledge could have been held within a select group, resulting in power from the control of knowledge (Thomas, 1996, 20). The physical difference between raw material and a finished object can create complex biographies that contribute to the construction of value that can be further enhanced by the exotic origins of raw materials (Needham, 1993, 163, Helms, 1993, 48). These constructions may draw on memories, either from direct experience or oral tradition. In the following examples it can be seen how the source of metal was protected, enabling a group to control access to the raw materials and heighten the mystery of its origins.

In the first case the sources of mineral wealth could be protected through restricted access by the use of traditional stories. In Native American legend, Isle Royale, the source for much of the early copper in the Great Lakes region of North America, was protected by a powerful spirit called a Manitou that would curse or destroy any interlopers attempting to gain access to the island (Martin, 1999, 203). By controlling access by cultural means, metal workers protected the mine and the knowledge of the source of metal.

In the following example, knowledge is restricted through obscuring origins. Bronze does not occur as ore, it can only be created by combining copper with another metal. Because of this, bronze does not have a single place of origin. Thus the true source of bronze is known only to those who participate in the initial phases of the alloying process. This is demonstrated in the convoluted procedures for making the bronze daggers found in Poros in Crete, where the various steps in their manufacture were all conducted in different locations. Lead isotope analysis linked the copper ore to Kythnos in the northwest area of the Cyclades, but the ore was brought to Chrysokemio to be smelted. The refined copper was then taken to Poros, where the finished daggers were produced. By proceeding along such a complex chain, the origins and refinement of the metal is obscured and control over the manufacture is exercised by those who arrange the transfer of the materials from one site to the next. The result is that the origin of the daggers is unknown, adding to their exotic nature (Doonan and Day, 2007, 8).

Time also creates a distance that contributes to the exotic. This could be seen in the examples of heirlooms, and also in objects whose origins have become connected to myths. In the Indian district of Meerut, slag is collected from a site and made into antidotes for poisons. The site is connected to an event in the First Book of the *Mahabharata* where a passage describes the sacrifice of snakes. The fragments of slag are believed to be the remains of the bones of the snakes that died in that event. In addition to its healing properties, the slag is also used for funeral rites and has connections to life, death, and the next world (Lahiri 1995, 130).

Exotic origins also enhance the value of objects as seen in the manufacture of the brass masks of Obanifon, the patron deity of the Obo. The masks are cast at distant villages and are valued by the Obo smiths and chiefs in northeast Yorubaland. The distance is associated with the secrecy of the deity that the mask represents (Aremu, 1987, 308).

## Prestige and value

In non-monetary societies, surplus wealth could not be invested and instead a network of social indebtedness, interdependence, and support create prestige as the goal of investment. Prestige is based upon relationships in which one person, family or group owes another and must reciprocate or risk indebtedness and lower status (Mauss, 1990, Rowlands, 1980, Gregory, 1982, Bradley, 1998, 138).

In a society based on prestige rather than currency, the balance is always precarious. Rather than obtaining and storing valuable objects, prestige is negotiated through feasting, gift exchange, and other social activities. When a debt is paid, the two parties are on an even level. However, when objects are given to another party, the status is out of balance, and there is the chance that the gifts will later be given to others who will acquire more prestige. Gifts could also be returned with added value, so that the second party will gain prestige greater than that of the original donor, thus causing reversals of indebtedness. The cycle can be broken by creating a system of votive offerings in which valued objects are given to gods, ancestors, or other supernatural beings. In this way goods are taken out of the cycle, as supernatural beings are unlikely to return any of the offerings. By doing this, the spiral of accumulated goods is held in check and one's status is less likely to be threatened by others who could either return the goods or give them to another who could challenge one's level of prestige (Gregory, 1982, Strathern, 1988, 222). The items selected to be taken out of circulation also gain a heightened value, in that they are no longer commodities, but something apart from "the mundane and the common" (Kopytoff, 1986, 69).

## Constructing value from context

So far this chapter discussed the intrinsic values of metal, those properties that cannot be removed from the object, and properties that were culturally assigned that enhanced the value of metal and metal objects. Another consideration is the context of where metal is found. As we saw with the example of *La Secchia Rapita*, context provides an important clue to an object's value. Context influences an object's interpretation, however interpretations can be changed or contested either over time, or from the viewpoint of different people (Moreland, 1999, Holtdorf, 2002, 55). If the remains of our Modenese bucket were found in plough soil or had little in the way of context that would help in its interpretation, it might be valued as a relic, and its value would rest mainly on its age and rarity. However, if it was excavated from a context that indicated that it could have been specifically chosen for deposition (such as objects found beneath standing stones or in the terminals of ditches), or association with other objects such as in a hoard or burial, this could indicate that that the object had meaning that was relevant to its context.

In Chapter 5 it will be shown that a significant percentage of metalworking tools found in Britain come from hoards, and that only certain categories of metalworking tools appear to have been selected for deposition. While we will not be able to decipher the reasons for the choices people made in constructing the hoard, we can look at the objects and especially the tools to make inferences about the significance of metalworking activities.

The following section will explore those hoards defined by the presence of tools and metalworking materials in order to provide a foundation for understanding the significance of smiths and their tools in these deposits.

## Metal in ritual and hoards

Bronze hoards were first divided into different categories beginning with Evans' designation of hoards that were either personal property that was buried in times of trouble, merchants' inventory, or founders' hoards: the stock and tools of a metalsmith (1881, 456-69). Childe further defined founders' hoards as being "characterized by the presence of old and broken tools, obviously scrap metal collected for remelting, and often too of metallurgical tools, moulds and ingots of raw metal". Larger hoards were considered to be a supply of metal for the village smith that was buried in a time of danger (1930, 45). Childe did acknowledge that the hammers and chisels found in hoards were metalsmithing tools (1930, 228). However, tools were also included in his definition of domestic hoards, although he defined these hoards as having only a few elements of different types of objects. His definition of merchants' hoards also included tools and ingots in the form of torcs. Burgess believed that founders' hoards in the south-east indicated the importance of the scrap metal trade in that region. This was in contrast to hoards with weapons, which he interpreted as votive hoards (Burgess, 1974, 210). Childe did not define votive hoards based on content, but rather defined them as being located at special places such as rivers and springs.

The main division between utilitarian and ritual hoards was based on whether or not a rational explanation could be ascribed to them. Those that looked as if they were associated with industry or economics were defined as founders' and merchants' hoards. Although Worsaae (1866, 71), Hunt (1955, 99-100) and Muller-Karpe (1958, 34) all suggested that hoards with smithing tools or foundry debris could be votive (cited in Needham, 2001, 280), it was much later that the idea became more acceptable.

Levy (1982) recognised a strict division between utilitarian and ritual hoards, defining hoards with tools as being utilitarian. However, Needham was critical of Levy, saying that assemblages are not as easily distinguished as stated (Needham, 2001, 279).

> "Most if not all deliberate deposits were 'ritual' at one level or another, and yet, should circumstances permit and demand, some, if not all were also available for recovery. From this viewpoint, it may not be productive to perpetuate the ritual-utilitarian opposition, since ritual and utility are unlikely to have been mutually exclusive categories" (Needham, 2001, 294)

Needham also wrote about the careful arrangement of objects in hoards and that there was "something beyond a purely functional requirement in their act of burial" (Rohl and Needham 1998). "The fact that founder's hoards in some regions have a range of items linking them to the practice of metalworking does not in itself explain *why* they were deposited in the ground" (Needham, 2001, 280).

Needham opened the possibility for wide variation for interpreting depositional practices (Needham, 2001, 291). He challenged the "bi-polar" model of ritual/utilitarian deposition (Needham, 2001, 275) and brought up the possibility of the reverse of deposition. Some deposits (both utilitarian and votive) could have been made with the intent to recover caches of votive articles could have been retrieved re- and deposited repeatedly as part of a regular ritual. However, the longer time passes, the more likely the hoard is to be forgotten or lost (Needham, 2001, 287-288).

Richard Bradley considered that the context of all hoards, including utilitarian (founders' and merchants' hoards) as a significant factor in their definition (1998, 13). He also acknowledged that the line between utilitarian and votive hoards was not so clear as earlier authors had drawn them (1998, xix). The votive, or ritual hoard, could be construed as a means of securing favours from gods or ancestors, thus equating the value of the hoard with the requirements of a ritual or socio-spiritual contract (Sherratt, 1976, 259, Bradley, 1985a, 31, 1998, 39). In this case the value of the tools and metal is not connected to economics, but to spiritual values, in which the hoard contents were considered appropriate and meaningful ritual gifts. However, other interpretations saw ritual hoards as a means of creating and maintaining social power relations. By sacrificing quantities of metal, the prestige of those offering the wealth to the gods would be enhanced (Bradley, 1998, 16). Helms addressed this in terms of metal being a "nutritive life force" that was ritually returned to the earth in order to propitiate cosmic forces for the benefit of the community (Helms, 2012, 106, 110).

However, Pendleton rejects the concept of ritual hoards stating that there is a lack of evidence to support ritual activity (Pendleton, 2001). Barber counters his argument by pointing out that Pendleton does not define what he means by 'ritual', and does not offer an alternative explanation as to why metal objects were deposited (Barber, 2003, 76). Barber's view is that the mundane and ritual aspects of metal were "intertwined throughout the Bronze Age" (Barber, 2003, 166). Richard Bradley also recognised that the objects found in hoards that were previously considered utilitarian could be more rationally explained as a ritual deposit (Bradley, 1998, xix).

Barber noted that metal is thought of in terms of its function, and so its association with the metaphysical is often not considered, however its inclusion in hoards and other deposits demonstrates its value beyond utilitarian uses (Barber, 2003, 74, 76). In this sense it can be seen how the boundaries of ritual and mundane life are blurred

(Fogelin, 2007). These objects take the form of votive offerings to gods or ancestors, and associated with activities such as feasting, and competitive and conspicuous consumption (Bradley, 1998, 39, 112, 142).

Ritual life was connected to events that would bring wider communities together (Johnston, 2008, 281). Celebrating the regular events of social life such as weddings, funerals, harvests, or seasonal gatherings for exchange of goods reaffirms the community as a whole through a shared experience and as a means of ensuring "the well-being of the settlement and its inhabitants" (Brück, 1999b, 335, Helms, 2012, 105-6). Renfrew describes ritual as being 'time-structured', either connected to specific periods, such as seasonal or annual events, or those that are connected to the life cycle, such as birth or death (Renfrew, 2007, 116). These rituals are a shared practice, supported by the community and defines social groups (Lee, 1985a, 19, Kyriakidis, 2007, 295). It is a collective act, authorised and recognised by the community. "…although [ritual is] performed by individuals, [it] has an existence that goes beyond the individual performer" (Owoc, 2005, 262).

In all of the above cases the focus has been on defining hoards based on categories of objects or location rather than looking at the individual objects and how they might relate to each other as an assemblage, and especially how tools might relate to the other objects in the hoard. In Chapter 7 these relationships will be explored. In addition, the condition of all the objects found in these hoards, as well as the function of the various tools is all important indicators for interpreting hoards. Destructive acts such as flattening sockets, or jamming sockets with other objects, or breaking metal objects into fragments were done purposely. This thesis will explore the condition of all the objects that constitute hoards with metalsmithing tools in order to assess differences in categories of objects in order to interpret these hoards, and how the smith would have had a significant role in the creation and destruction of metal objects.

## Fragmentation as a ritual act

One characteristic of founders' hoards is the fragmentation of objects found in the hoards. Early authors believed that the objects were already broken and given over to the smith for recycling (Evans, 1881, 456-69, Childe, 1930, 45), while Burgess felt that depositional conditions were a major contribution to their fragmentary state (1968b, 25). Both Turner and Brück looked at the fragmentation of objects in hoards and recognised this as not so much a reduction of objects to fit in a crucible, as the having a correlation to death, transformation, and regeneration (Turner, 1998a, 135, Brück, 2006b, 306). Brück interpreted the hoards as a model for social reproduction, identification, and the transformation of the members of the community through the various phases of life and death (Brück, 2006b, 310). In these theoretical frameworks, the interpretation of hoards is far more complex than the original ideas of a cache of supplies, or concealing valuable material, and that links could be drawn between the pyrotechnical processes of metallurgy and cremation (Barber, 2003, 78).

Taylor saw fragmentation not only as a ritual act, but further defined it as a means for removing objects from circulation in a potlatch-type ceremony, where elite could show power by deliberately destroying objects that symbolised their wealth and offering it to the gods (1993, 41-42). The fragmentation of objects was also explored by Chapman who examined the dichotomy of enchainment and fragmentation, in which fragmented objects represented enchained social relationships that could include family groups or exchange networks (Chapman, 2000, 45). Brück connected the destruction of metal objects in hoards with that of the human life cycle (Brück, 2001b, 157). The creation of metal objects and their ability to be recycled provided instrumental metaphors for the formation of social identity where they could be combined to make a composite object with contributions from many, just as a community is composed of individuals (Brück, 2006b).

Turner interpreted the deliberate destruction and fragmentation of metal objects as a metaphor for death and transformation, and linked to the annual cycle. She pointed out that although the objects were broken in a way that would optimise them for fitting into crucibles for re-melting, many objects found in the same hoards were not fragmented, (1998a, i, 78, 146).

Smiths would have been responsible for breaking up the metal objects and the act would place them in a position to fulfil a primary role in a ritual act (Bradley, 1998, 202, Barber, 2003, 168, Hastorf, 2007, 81). In the previous chapter it was described how metalsmiths were associated with healers and shamans, or filled those functions themselves. Their ability to transform metal from solid to liquid and back again was seen as control of the elements through secret knowledge, and recycling could be interpreted as a metaphor for death and renewal (Jones, 2002, Brück, 2006b, 306). These acts of creation and destruction become a ritual performance, where the smith's specialised knowledge and use of symbolically charged tools could be used to manipulate power within the community (Fogelin, 2007, 61). The metal objects made by smiths that were part of the mundane sphere gained significance through their association with tasks that are also a part of the ritual sphere (Bradley, 1984, 73, Fogelin, 2007, 61). They became elevated and were ascribed both power and value and as a result were irreplaceable (Hood, 2009, 84). Thus tools acquired symbolic meaning and were elevated to objects that became appropriate to include in ritual deposits (Lee, 1985b, 21, Barrett, 1996, 397, Fogelin, 2007, 66). This symbolic meaning, experienced either by handling or observing the objects, including witnessing their destruction at the hands of smiths, creates a focus for the community that strengthens social roles and traditions (Brück, 2000, 284, Fogelin, 2007, 57).

These interpretations of hoards sought to categorise them into clearly defined groups based upon contents and then subdivided as to whether they were votive or utilitarian. Interpretation of these assemblages is made more difficult when the interpretation of a hoard is made by the object class of its contents rather than the assemblage as a whole (Osborne 2004). Turner categorised hoards based on the types of metal objects found in the hoards, the size of hoards, and if the hoards contained objects from one category or were mixed (Turner, 1998a 71ff). While she acknowledges that these hoards are connected to metalworking, she does not see them as stored inventory, but does see them as a "deliberate reference to the metalworking process" Turner, 1998a, 118-119).

In archaeological literature the early definitions of hoards are still accepted. Founders' hoards are defined as assemblages that include scrap metal in the form of broken agricultural tools such as axes and sickles, ingots, metalworking debris, or metalworking tools. However, agricultural tools are found also in votive and merchant hoards and since founders' hoards frequently do not include ingots or casting scrap, the one unifying factor of these hoards is the presence of metalworking tools. If there is some significance to metalworking tools as a means of defining hoards, then they deserve closer examination as to their possible function as both tools and symbols.

As seen in this section, there is no single term to describe hoards that include metalsmithing tools, and that the term founders' hoard has accumulated too many defining characteristics. However, these assemblages containing metalsmithing tools do contain elements that would indicate that they had more cultural significance than a buried accumulation of tools and scrap metal would imply (Osborne 2002).

## *CONCLUSION*

This chapter established how the intrinsic properties and social negotiations made metal valuable. In order to understand the processes of bronze metalwork, there must also be recognition of the social context of the craft as well as the skills and tools necessary for metallurgical practice (Roberts, 2009b, 464). The smith's knowledge of the skilful use of tools, the processes through which metal was transformed from raw material to a finished object, and the properties of metal resulted in metallurgical performances to create objects that could be either utilitarian, or elite goods associated with prestige and ritual. None of this would be possible without the smith's tools. Tools are the key element that ties value, creation, and the identity of smith together, and the recognition of both the value and function of tools will provide the materials with which to begin reconstruction the smith's tool kit.

Thus far, the thesis has established a foundation that moved away from earlier archaeological models of metalworking and smiths. It had been accepted that the practice of metalwork created valuable objects that had meaning that was culturally constructed, but this thesis recognised that tools and the circumstances of their depositions are of primary importance in understanding the craft and its practice in Bronze Age Britain. This thesis also recognised the smith as a master of the craft, who in various cultures, was seen as a descendent of gods, functioned as a shaman with the power to heal or destroy, and a person who created powerful and prestigious objects that retained that essence even when the object passed from one owner to the next.

Smiths and the objects they make are bound together by the tools that are necessary to practice their craft. The following chapters will examine the Bronze Age metalsmithing tools that have been found in Britain. Beginning with Chapter 4, the types of metalsmithing tools found in British Bronze Age contexts will be explored and compared to contemporary tools and their equivalents in modern workshops. This will be the first step in a study of the metalworking tools found in Britain that will establish a basis for understanding the organisation of the Bronze Age metalsmith's toolkit.

# Chapter 4 Reconstructing the Toolkit

*We shape our tools and thereafter our tools shape us*

*~John M. Culkin, S.J. (1968)*

In the previous chapters we saw how tools are important in understanding both the processes of metalsmithing, how they help shape the identity of smiths, and how they are used to make valued objects. This chapter seeks to establish the foundations for a comprehensive framework that will create a consistent and clearly organised system for understanding the metalworking practices of the British Bronze Age. Such a system would facilitate valid interpretations, and offer a broader perspective from which larger trends could be seen (Roberts, 2008, 48, Brindley, 2008, 1).

This chapter will first explore metalsmithing tools both as objects used and produced by metalsmiths in the British Bronze Age, and as artefacts of Bronze Age metalsmithing. It will begin with a brief survey of the history of metalsmithing tools, followed by an organised examination of the types of tools needed to make metal objects based on function. Finally the British Bronze Age tools will be placed in typologies, with a new typology developed for classifying hammers.

By organising metalworking tools based on function, questions can be addressed about how they were used, what objects could they have been used to make, and how tools have been modified to accomplish specific tasks. By systematically examining the tools found in Bronze Age contexts and exploring their functions, insights can be gained into details of the craft of metalsmithing.  This will lay the groundwork for organising a system in which tools can be connected to the objects they were used to create.

## Introduction to the Bronze Age smith's toolkit

The majority of the published literature concerning metalworking tools is contained in individual reports on objects and hoards such as Burgess and Coombs volume on Bronze Age hoards (1979) or Tylecote's studies of archaeometallurgy (1968, 1986, 1992, Evely, 1993a). Other sources are found in regional studies, excellent examples of which are Turner's 1998 *A Re-interpretation of the Late Bronze Age Metalwork hoards of Essex and Kent*, Pendleton's 1999 *Bronze Age Metalwork in Northern East Anglia,* Evely's

1993 *Minoan Crafts: Tools and techniques, an introduction,* and Ó Faoláin's 2004 *Bronze Artefact Production in Late Bronze Age Ireland* (Turner, 1998a, Pendleton, 1999, Ó Faoláin, 2004). All of these volumes provide detailed descriptions of metalworking tools from their respective regions and countries. However, for most of the British literature, tools are listed without description other than a basic type such as "hammer" or "chisel", or in some cases "instrument". Occasionally tools are given brief descriptions, however these are usually based on decoration rather than the tool's function (for an example see Davies, 1979). Two rare exceptions are Northover's analysis of the drawplates that are part of the Isleham Hoard (1995) and Ehrenberg's article on Bronze anvils (1981). By taking a broader view, this thesis will be able to look at larger trends and to see if there are regional variations in tool types, and metalworking traditions.

In order to understand the range of tools used by Bronze Age metalsmiths, a search was made for metalsmithing tools in literature and databases. In addition to traditional literature searches, two online resources, Archaeology Data Services (ADS http://archaeologydataservice.ac.uk/), and the database for the Portable Antiquities Scheme (PAS http://finds.org.uk/) were invaluable for locating specific types of objects. These sites not only provide information on current and past finds, but also provide bibliographical information. The ADS, and The British and Irish Archaeological Bibliography (BIAB http://www.biab.ac.uk/) also contain links and bibliographical information for accessing grey literature. Since these sites are constantly updated, frequent searches were made. The assistance of curators in finding objects in museum collections that were not otherwise listed on public databases or published literature, was also invaluable. The tools were then categorised according to inferred function based on their nearest modern equivalent. Similar work was done by Eveley (1993a, 1993b) for material relating to Minoan crafts, where she compared tools cross-culturally and to modern equivalents.

However, before assigning function to tools, it is important to examine how they were developed and how they filled a need to accomplish specific tasks. This provided a foundation for understanding how tools were altered in response to new media, and how metalsmiths continued to adapt tools in order to create a wider range of objects.

## THE CONTEXT OF BRONZE IN THE BRONZE AGE

When Thomsen defined the Three Age System based upon stone, bronze, and iron, it was an arbitrary division based upon the objects of material culture that were considered significant at that time. Beginning with its appearance at the end of the Neolithic, metal became a means for explaining the development of social complexity and economic power. The introduction of metal represented the proliferation of technology; the spread of ideas, control of resources, and expansion of trade routes were seen to be vital for economic and technological progression (Lubbock 1869, Evans 1881, Childe 1930, Hawkes 1940). Changes in metal and pottery styles were used for comparative dating. Periods in British prehistory were named for significant objects or hoards, and regions were defined based finds of metal objects (Burgess 1974).

At that time, little was written about the social structure of prehistoric Britain, and so the designation of periods based upon stone and metals gives them a significance that might not reflect their importance to Bronze Age communities. The discovery and use of copper, gold, and later bronze did not occur at a time when people changed how they lived or buried their dead. The arrival of metallurgy did not spark immediate change in social and economic systems (Bradley, 2007, 153, Barrett, 1994, 33, Parker Pearson, 1999b, 77), but only became a significant economic and social factor over an extended period of time (Deverenski and Sørensen, 2002, 119). Cultural changes came about through multiple social and environmental factors, of which metallurgy was only one facet. The conversion from stone to metal tools and the introduction of new metal objects was gradual, with some regions changing faster than others, underscoring the observation there was no real clean break between the Late Neolithic and the Early Bronze Age (Bradley, 1984, 69). Even the division of the Bronze Age into Early, Middle, and Late phases comes into question when it has been realised that most major cultural changes occur towards the middle of these periods rather than at the cusps (Bradley, 2007, 25).

Rather than being a replacement for other materials, or a factor in rapid social change, metal was a new medium gave rise to an entirely new category of people who became experts in working with the new material. Over time, metal and metal objects gained significance and value (Chapter 3), and while its presence did not change other significant social factors, it did make available new types of ornaments, tools, and weapons that could signal social status, make tasks more efficient, or more deadly. Metal made new types of objects possible, but also required specialised tools with which to make these objects. The development and progression of metal as a craft underscores the need for the study of metalsmithing tools and how they were used.

## A BRIEF HISTORY OF METALWORKING TOOLS

Perhaps while trying different types of lithic materials, it was discovered that some rocks deformed instead of fracturing. Native (pure) metals such as gold and copper have a ductile quality that causes them to deform rather than flaking. With repeated hammering metal could be formed into shapes or flattened into sheets using basic tools of stone, wood, or antler (Coghlan, 1951, 19, Tylecote, 1992, 1). These early techniques are seen in the oldest known examples of metalwork in Britain: earrings that were dated to 2100 BC and made of sheet gold 0.13 to 0.27 mm thick (Taylor, 1980a, 22). The tools used for making gold sheet metal would have been ground and polished to a glossy surface; otherwise any marks on the tools would be transferred to the softer metal.

Stone hammers were limited by both the way in which they could be shaped and by the qualities of the stone. Hammers could be ground to a flat or a domed shape, but higher profiles such as wedged-shaped faces or anvil beaks present a problem since most stones will have the tendency to chip or fracture. However, as the craft of metallurgy progressed and new techniques developed, specialised tools were needed to perform actions such as forming, chasing, and riveting. Bronze tools filled the need in that they could be cast into any shape. They were also unlikely to crack, and the faces could be repaired or maintained by hammering or sanding with minimal loss to the tool. Anvils could also be more complex, with extended beaks and holes for drawing wire. However, the development of bronze tools did not mean that tools of stone, antler or other media fell out of use. Stone tools still have their place in the modern workshop in the form of hones and burnishers.

No Early Bronze Age tools, either of stone or metal, have been identified as being specifically for metalworking. However, bronze awls and scribes are found in Early Bronze Age burials and among their many possible uses, these tools could have been employed for engraving designs onto sheet metal. Stone hammers could have been used for several purposes and might not have been specialised for metalworking. Other tools made of wood or antler would not endure in the archaeological record.

Metalworking tools made of bronze began to appear in Britain at the end of the Middle Bronze Age and the beginning of the Late Bronze Age, at a time associated with the Ornament Horizon (1400–1100 BC) (Roberts, 2007). During this period torcs, bracelets, rings, and pins were made of tin, gold, and bronze. While some of these ornaments were cast, some objects such as pins needed to be hardened by hammering. Others such as torcs and bracelets might be shaped by hammering or decorated with lines incised by chasing or engraving. The earliest bronze hammers also date to this period and are found in the Taunton Workhouse Hoard in Somerset, and the Hambledon Hoard in Winchester.

It was not until the Late Bronze Age (c. 900 BC) that a greater variety of metalsmithing tools began to appear. These tools included hammers, chisels, and anvils, all of which varied greatly in size and shape. This increase in the types and quantity of tools indicate more and different types of objects being made that required specialised tools. One example of this specialisation is the introduction of riveting, as seen in Late Bronze Age cauldrons. Cauldrons are complex constructions of both cast and sheet metal elements and are assembled by riveting the various parts together and provide an excellent example of the range of metalworking techniques used to create a single object. This technique required specialised hammers and supports (dapping blocks or snaps, and sets) in order to join pieces of metal. The evidence for these specialised tools is seen in the introduction of cauldrons with domed or spiked rivets in c. 700 BC (Gerloff, 1986, Northover in Gerloff, 2010, 39).

Despite the wealth of metal objects, few Bronze Age metalworking sites have been excavated and no Bronze Age metalworking shops have been discovered with tools in situ. Metalworking sites have been primarily identified through the identification of hearths that contained droplets of cast metal, or casting debris such as slag or fragments of moulds or crucibles. Most tools have been recovered as stray finds or as a part of hoards. In the case of hoards it will be shown in Chapters 5 and 6 that these depositions are unlikely to represent a complete metalworking tool set. Because of the lack of work site contexts, it is necessary to organise the metalsmithing tools we have in order to understand what tools are present and what might be missing.

## *THE TYPES OF BRONZE AGE METALWORKING TOOLS: BRITISH COMPARED TO OTHER TYPOLOGIES*

In *Jewelry Concepts and Technology* (1985), Oppi Untracht organised a system for categorising metalworking tools. His categories consist of **striking or percussive impact tools** (hammers, mallets)**, indirect striking percussion tools** (any tool that is struck by a hammer, including chisels, stamps, rivet setting tools, and chasing tools)**, compression tools** (anvils, swages, drawplates, mandrels, burnishers, and rollers)**, holding tools** (tongs, pliers, tweezers, vices, and tools that would include substances for adhering, such as a shellac covered stick)**, cutting tools** (shears, saws, rocking blades, hollow dies, chisels, and punches),and **metal removal tools** (drills, gravers, scribes, and tools used for abrasion). These classifications are based on conceptual work principles, and provide a means for organising metalworking tools based on function. Using Untracht's definitions as a basic framework, the tools recovered from Bronze Age contexts can be placed within these groups. Using Untracht's system we can identify the tools that are available from the British Bronze Age (**Table 4.1**). From this point we can begin to establish associations between different tools and better understand their function.

| Type of tool | Examples found in Bronze Age assemblages |
|---|---|
| **striking or percussive impact tools** | hammers |
| **indirect striking percussion tools** | chisels, rivet setting tools, and chasing tools |
| **compression tools** | anvils, swages, drawplates |
| **holding tools** | tongs, pliers tweezers, vices |
| **cutting tools** | shears, saws, blades, punches |
| **metal removal tools** | drills, gravers, scribes |

**Table 4.1 Tools found in Bronze Age contexts**

The following sections list the types of tools found in British Bronze Age contexts along with their contemporary (if any) and modern equivalents.

### *Anvils, stakes, swages, and drawplates*

Many materials can fulfil the role of an anvil. Smooth stones of sufficient hardness can function as a surface for hammering out sheet metal or as a stable surface for removing excess metal from a cast object. The distinctive 'pecking marks' on sandstone saddle querns recovered at Lough Eskragh were considered to be the result of their use as anvils (Williams and Pilcher, 1978, 39, 41-3). Hardwood also functions well as an anvil. A tree stump provides a flat, stable surface, and can be carved to create a *swage*, a hollow shape into which metal can be hammered to create a three dimensional object.

In addition, small anvils similar to modern jeweller's anvils are also cast from bronze. These Bronze Age anvils, like their modern equivalents, come in a variety of shapes. Typologies exist for anvils found on the continent, where they are divided into categories based on their complexity, from simple blocks to beaked (or horned) anvils (Ehrenberg, 1981, 14, Kuijpers, 2008, 97). Of the examples found in Britain, the majority can be identified as beaked anvils, such as the one found in the Inshoch Wood Hoard in Inverness (**Fig. 4.4**). These resemble modern miniature goldsmith's anvils that have a flat striking surface on the top, although a few examples, such as one in the Lusmagh Hoard and two individual anvils from France have peaked working surfaces. This modification is beneficial for creating a rolled edge on sheet metal objects, such as armlets and bracelets. These anvils usually have a horn at one or either end and a spike on the bottom that enables the anvil to be pounded into a stable work surface such as a tree stump (Ehrenberg, 1981, 15). A third category describes complex anvils that include features such as holes that could be used for drawing wire. Jantzen (2008, 387) lists a total of 61 anvils found throughout Europe, with six coming from Britain, and five from Ireland.

Stakes are a specialised form of anvil, and also have a variety of forms that serve specific functions. They are characterised by having a tang or shank that is held in a vice or pounded into the end grain of a tree stump (Untracht, 1968, 245-6). The striking platform can be either vertical, or "T" shaped, with the arms of the "T" shaped to facilitate the creation of different forms. The Scottish anvil found in Sutherland would more properly be described as a stake (Childe, 1946, 10-11). Evely (1993a, 101-102) identified two different stakes in Minoan Crete, one a "T" shaped and the other a curved snarling iron used for repoussé. In addition palstaves and socketed axes can also be mounted upright to serve as a stake.

Drawplates are metal blocks drilled with a series of increasingly small holes and are used for making wire. Metal is annealed and then formed into long, slender flat sheets. These are then twisted to form wire (Oddy, 1977). The wire is then annealed again and pulled through the holes in the drawplate. The process is repeated until the wire is the desired dimension.

Drawplates can also be incorporated into anvils, such as the anvil from Lusmagh, County Offaly, Ireland that has four holes ranging in size from 2.5 mm to 1 mm (Maryon, 1938, 248-9). The anvil from Sutherland (Childe, 1946 10-11) and an anvil from Fresne-la-Mere, Normandy (AN 1927.2322), now in the Ashmolean Museum, have a series of grooves that could also function as a swage or drawplate (**Fig. 5.9**). For these a flat stone or piece of bronze would be clamped or held tightly against the groove in the drawplate to produce a half-round wire. The half-round wire from the Donhead St. Mary's Hoard (Salisbury & South Wiltshire Museum) has fine striations running along the length of the wire that was likely to be the result of drawing through this type of swage.

### *Chisels, chasing tools, and stamps*

Chisels, when struck by a hammer, are the most efficient means for removing excess metal such as flash and casting jets from cast objects. They can also be used to create different forms of decoration. Incised lines can be drawn across the surface using an awl or scraper, but deeper lines can be cut by chasing. For this a chasing tool that resembles a small chisel is guided by one hand while being continuously hammered. Different blade shapes are used to create different effects and textures (Untracht, 1968, 97). Examples of this technique can be seen in the decoration of objects such as lunulae or engraved 'rain patterns' on Early Bronze Age axes (Schmidt and Burgess, 1981, 45).

Another use for the chisel is the decorative technique called repoussé. For this the design is worked on the reverse of a sheet metal object using various punches and chisels while the object is supported on a malleable surface such as a sandbag or bowl filled with pitch. This action pushes the metal outwards to create a raised design on the front surface (Untracht, 1968, 97).

In Chapter 5 it will be seen that hundreds of chisels have been and continue to be found in Britain. Because of this an exhaustive list of all the potential metalworking chisels found from the Bronze Age in Britain was beyond the scope of this thesis. This is in part because the category is poorly defined. This is not the fault of archaeologists, but rather the aptness of chisels to cross craft categories. For instance, thinner chisels would be unsuitable for metalworking and are more likely have been used for crafts such as leather or woodworking. There is also difficulty differentiating some types of chisels from small flat or socketed axes. Two excellent examples of chisels that could have been used for metalworking are found in the South Wiltshire Heritage Museum in Devizes (STHEAD 207 and STHEAD 312) (**Fig. 4.1**).


**Figure 4.1Bronze chisel and bone handle, reproduced courtesy of Wiltshire Museum, Devizes**

These chisels were both discovered with bone handles. If the handles were not preserved, the chisels would have been assumed to have been axes. However, the tools could serve both purposes depending on how they were hafted.

Modern chisels and decoration tools also come in a wide variety of shapes. Frequently smiths will either make their own, or will alter commercially made tools to suit the job at hand. The knowledge that this is a general practice shows the difficulty in defining similar tools in antiquity. These examples highlight the need to recognise the multiple functionalities of tools and the importance of context.

Evely (1993a, 11-15) lists six types of chisels used in Minoan Crete. The types are based both on physical differences in manufacture and on use-wear; from these the author infers the possible function of the tools. O'Connor (1980a, 174, 1980b 528-530) lists socketed chisels from North-eastern France, Belgium, and the Netherlands, noting their resemblance to chisels found later in south-eastern Britain and Ireland.

Coombs created a typology for Bronze Age chisels found in Britain, defining four basic blade types (Coombs, 1971, 260) (**Fig. 4.5**). In addition to these there were mortising chisels, flat-tanged chisels, a Cardiff type that had rivet holes, and miniature socketed axes (Coombs, 1971, 263-268). Coombs wrote that the development of chisels was a progression from simpler towards more sophisticated designs (Coombs, 1971, 261). This is an unfortunately simplistic view, and as will be shown in chapters 6 and 7, the complexity of tools design is based upon function rather than it indicating a developmental sequence.

### *Hammers*

The majority of bronze hammers found are socketed hammers dating from the Late Bronze Age. There are some rare exceptions, such as a tanged hammer from Beechamwell in East Anglia (**Fig. 4.17**) and two Middle Bronze Age socketed hammers from Winchester and Taunton.

In Britain, two broad types of hammers can be identified based on the shape of the face (Turner, 1998b 81, 156, 227, Ó Faoláin, 2004 249-251). The most common one was found both in hoards and as individual finds, and has a profile in which the face is faceted with an obtuse angle of approximately 130°. The apex of the face is offset so that it is divided into two sections, in approximately 2:1. In these hammers the casting seams are not symmetrical between the top and bottom as they are with a socketed axe, but rather they are off-centre and line up with the placement of the apex on the face of the hammer (**Figs. 4.8 & 4.9**).

The other type of hammer has a symmetrical peaked face that resembles a modern cross peen hammer. On these hammers the flashing runs along the middle of the sides, similar to socketed axes (**Figs. 4.8 & 4.11**).

Other socketed hammers fall into these two broad categories, although variations are also seen.  Examples consist of hammers with a more rounded face that could have been either a result of wear on the first type of hammer, or it was deliberately shaped for *planishing,* smoothing the surface of hammered sheet metal (Untracht, 1968, 243, 249). Others have a face that is smaller and narrower, and resemble modern hammers used for spreading rivet heads (Untracht, 1968, 311-315). A complete typology for British Bronze age hammers is provided in the second half of this chapter.

### *Comparison to contemporary hammers*

Evely (1993a) identified both socketed and shaft-hole hammers from Minoan Crete. These came in different weights and shapes that would indicate function, such as heavy sledgehammers, or hammers with rounded faces used for sheet metal work (Evely, 1993a, 97).

Both O'Connor and Coombs identified two types of socketed hammers in Britain, one that was short and broad, as seen in the Bunwell Hoard (**Figs. 4.8 & 4.9**) and a slender hammer that is typified by the hammer from the Isleham Hoard (**Figs. 4.8 & 4.10**). Hammers similar to the former were also found in Brittany and Aquitaine (Coombs, 1971, O'Connor, 1980a, 137). Other hammers from hoards in Kent resemble others found in the Plainseau and Marlers hoards in France (O'Connor, 1980a, 176).

Jantzen (2008, 362ff) recognised two main types of hammers on the Continent: ones with a peaked face (*dachförmiger Bahn* "roof-shaped") and others with a domed face (*gewölbter Bahn*), while Jöckenhovel (1982) catalogued six types of German metalworking hammers that ranged from round to rectangular, and had flat, domed, and peaked faces.

Images of hammers in antiquity are rare, however Hephaestus is depicted on Attic red figure pottery (c. 525-420 BC) carrying a slender, almost delicate, wedge-shaped hammer that is hafted through a shaft hole toward the back of the hammer head (Fineberg, 2009 Figs. 13, 14, 15, and 17). The weight of this hammer would be distributed similarly to that of a socketed hammer, and the general shape resembles some of those found in the Bronze Age.

### *Blowpipes and bellows*

A charcoal fire does not have sufficient heat to melt copper or bronze, and so the temperature must be raised by increasing the oxygen. The least technical means of accomplishing this would have been the use of blowpipes. These were either made of reed, or reed tipped with clay (Coghlan, 1951, 67, Forbes, 1971, 114). Forbes (1971, 132) described an account by de la Vega who witnessed Inca natives melting copper, employing eight to twelve men using blowpipes to provide sufficient oxygen for the process. Similar scenes are depicted in Egyptian murals at the Tomb of Mereruka, in Saqqara (Childe, 1930, 30). Blowpipes are also used to blow dross and charcoal from the surface of molten metal before pouring.

Bellows are a more efficient means of providing oxygen to the furnace and can be operated by one or two people. Because bellows would have been made of organic materials, the only available evidence for them are *tuyeres*, a tube made of refractory material that runs from the bellows to an opening in the furnace (Forbes, 1971, 115).

### *Crucibles and moulds*

Crucibles are necessary for containing molten metal, and pouring it into moulds. These are made from clay bodies that include tempers that allow the clay to withstand high temperatures and thermal shock (Howard, 1982, Evely, 1993b, 346). The most common forms seen in prehistoric Britain are a sub-triangular bag shape (Tylecote, 1986, 96).

Moulds were made of clay, stone, or bronze, in one or multiple sections or *valves.* For multiple piece moulds, the valves are held together with cord, wire, or internal pegs. As with crucibles, clay moulds were made with clay paste recipes that would help withstand high temperatures. Moulds were also frequently made with two types of paste: a fine-grained, porous interior paste that would leave a smoother finish on the cast object and allow for gasses to escape, and a coarser, stronger outer layer (Tylecote, 1986, 89-92, Evely, 1993b, 353).

In Britain the preferred materials for stone moulds were fine-grained sandstone or steatite; schist was also used in Ireland (Tylecote, 1986, Ó Faoláin, 2004).

Moulds made of bronze came into use in the Late Bronze Age. It has been debated whether these were used for casting bronze axes, or for casting lead patterns (Tylecote, 1986, 92-3). However, experimental work described in Chapter 6 has shown that bronze can be cast directly into these moulds.

### *Other tools*

Awls, gravers, and scribes are all necessary tools for incising designs into metal, but also for marking lines prior to doing work such as chasing, repoussé, or cutting. These tools, like chisels, could have been used for many purposes. In these cases their context could indicate their association with metalworking.

Tweezers have been found since the Early Bronze Age and are most commonly described as objects for cosmetic purposes. However, they are also an essential tool for the metalsmith, not only for picking up small objects that are too hot to be handled, but also for manipulating small objects where fingers would be too clumsy.

Tongs are necessary for casting in order to pick up and hold hot materials. Although bronze tongs would be far more durable, wooden tongs dipped in clay slip are frequently used in experimental work.

Punches and drill bits are necessary for creating holes for attachments, including rivet holes. The punch from the Wiltshire Heritage Museum, Devizes (**Fig 4.6**) and the bronze drill bit from Runneymede (**Fig 4.2**) provide bronze examples, although flint or stone drill bits would also function well for drilling metal.


**Figure 4.2 Bronze drill bit (photo by author © Trustees of the British Museum)**

Examples of individual tools exist, such as the drill bit from Runnymede, the vice from the Bishopsland Hoard in Co. Kildare, Ireland (Ó Faoláin, 2004, 48), and the tongs from the Heathery Burn Hoard (Durham) (Britton, 1971). There is also a possible snap, a type of rivet setting tool, in the Lusmagh Hoard (Ó Faoláin, 2004, 251). While not identified as such, the tool has a rod-like body with an end that widens to a 23 mm diameter dished circle (**Fig 4.3**). Such an object would be used to support a rounded rivet head while the shank end of the rivet is set and hammered flat (Untracht, 1968, 434). While there is some doubt as to the positive identification of the function of these tools, they do represent objects necessary for metalworking.


**Figure 4.3 Possible rivet snap, British Museum (photo by author © Trustees of the British Museum)**

## TYPOLOGIES FOR METALWORKING TOOLS

Typologies have been created to serve a variety of purposes. Early studies used typologies to understand socio-political and economic systems (Childe, 1930, 55-6), to illustrate both evolution and degeneration of stylistic change, to understand outside influences on local cultures (Clark, 1957, 135-7), or for creating chronological sequences (Burgess, 1974).

Both Tylecote and Northover used a typological approach based on scientific analysis that went beyond the physical appearance of metal objects. Here, understanding metalworking technology and alloys added new insight into typological change (Northover, 1982, Tylecote, 1992, 19, 42).

For this study typologies for British Bronze Age chisels and anvils were chosen based on function, and a new typology for hammers was created. Similar categorisation was done by Jöckenhovel (1982) and Jantzen (1982) for bronze tools of Europe, and Ehrenberg for European Bronze Age anvils (1981). While Coombs (1971) created a typology for British Bronze Age tools, much of it was based on decoration and size rather than function.

In order to construct a typology based on function, tools were examined and grouped according to characteristics of the working surfaces, noting variations, and finally comparing them to the nearest modern equivalents. A similar study of Minoan tools was produced by Evely in which tools were catalogued and compared to their contemporary and modern counterparts, in order to interpret their use. (Evely, 1993a).

For this thesis, three main types of metalworking tools (anvils, chisels, and hammers) are found in sufficient numbers for typologies to be considered. Other metalworking tools exist as individual objects, such as the tongs and the vice mentioned above. An inventory of tools was compiled and then assembled in databases (**Appendix 4**).

## ANVILS

Six anvils have been found in Britain and Ireland, and shapes vary between types that are single stakes to complex beaked anvils. These anvil types have been organised and described by Ehrenberg (1981). Ehrenberg's typology divides anvils into three types. **Simple anvils** have one or more work surfaces, and may have a spike for securing it to the work surface. **Beaked anvils** have a work surface in addition to one or two beaks, or horns and resemble a modern goldsmith's anvil. These also may have a spike. **Complex anvils** can have more than one beak, or more spikes, so that the anvil can be mounted in different positions. There might also be grooved surfaces that could function as swages, or small holes that could function as drawplates (**Fig 4.4**). Based on Ehrenberg's typology, three of the anvils found in Britain are simple anvils, one beaked, and two are complex. Of these, the anvil from Oykel is a rare complex anvil with notches and a hole that could be used for drawing wire. It should be noted that one ingot examined in the collections at Colchester Museum was listed in the museum catalogue as possibly having been used as an anvil, based on flattened surfaces that might have been caused by hammering.

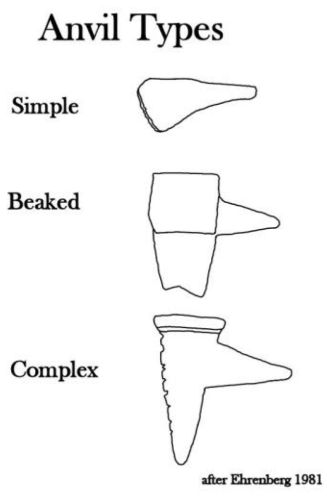



**Figure 4.4 Anvil types**

It is also noted that all of the anvils found are small, resembling modern jewellers' anvils. However, this does not indicate that they were exclusively used for small ornaments. Such anvils should instead be seen as tools that can be used incrementally to make larger objects, since the working surface of any anvil does not necessarily need to be larger than the face of a hammer.

## CHISELS

Chisels present a problem in that there are many different types with wide variation due to individual manufacture and changes from wear and maintenance. The difficulty in defining types of chisels is that they are easily modified and change constantly during use. As the blade wears down, it requires re-sharpening and hardening by hammering. This hammering can flare the blade and if it was desired for the blade to be restored to its original shape, the chisel would need to be sanded or dressed, thus decreasing its size.

In addition, not all chisels are suitable for metalworking. Some are thin and could be better assigned roles as leatherworking tools. With some chisels it is unclear which end was the blade and which was the tang (if there was even that distinction for using the tool at the time). However, all available chisels that were part of hoards were examined in museum collections with the aim of identifying if they were suitable for metalworking.

Coombs (1971) gave detailed descriptions of chisels defining four basic blade types: Type 1 is narrow and straight sided, Type 2 is broad and straight sided, Type 3 has concave sides, and Type 4 has a convex curve with a "crinoline outline". These were combined with four stop types: *a* has an evenly expanded swelling, *b* has side stops or lugs, *c* has a stop with a flat top and convex underside, and *d* a stop that is 90 degrees to the blade and tang (Coombs, 1971, 260) (**Fig. 4.5**). In addition to these there were mortising chisels, flat-tanged chisels, a Cardiff type that had rivet holes, and miniature socketed axes (Coombs, 1971, 263-268). Miniature flat axes and palstaves could also be added to this list.

| Chisel blade types | | | | Chisel stop types | | | |
|---|---|---|---|---|---|---|---|
| **Type 1** | **Type 2** | **Type 3** | **Type 4** | Type *a* | Type *b* | Type *c* | Type *d* |

**Figure 4.5 Chisel typology after Coombs**

The chisels examined fit into Coomb's typology with a Type 1 found in the Salisbury museum (1998 9-1 331) and a Type 3 in the Winchester Museum (117.2), with most falling into the categories of those that resemble miniature flat or flanged axes or socketed tools. Many of the chisels were fragments and were difficult to identify as to a type. One chisel from the Wiltshire Heritage Museum fit Coombs Type 2a, but has a slightly flared blade. Three different tools described as various types of chisels, could also serve as chasing or repoussé tools. Another chisel in the Wiltshire Heritage Museum (DZSWS 1982.39) (**Fig. 4.6**) is rounded at one end, with a flattened, burred surface on the other. This tool could be used as a tool for repoussé work, and could also have served as a punch for cutting holes in sheet metal. An object in the hoard in the Northampton museum (119.29.1) is described as a mortising chisel. However the broken end has not been cleaned and irregularities in the surface could indicate that rather than having a rough broken end, the texture could indicate that it might be a stamp or repoussé tool.


**Figure 4.6 Possible repoussé tool or rivet punch, reproduced courtesy of Wiltshire Museum, Devizes**

### *Variations*

One socketed chisel (AN 1927.2460) has fine chevron designs inside the socket (**Fig. 4.7**). The purpose for the chevrons is unknown, although it is possible that they could function to secure the handle more tightly, or could indicate that the core for the socket was made using a cuttlefish bone (cuttlebones). The texture of cuttlebone could create the chevron pattern as seen in the socket once the core was removed. Cuttlefish are found along the coasts of Britain and Wales and the thick calcium "bone" is frequently found on the shores around the UK (Arkley et al., 1996). The bone is widely used in jewellery making today, usually as a mould for casting small objects (Untracht, 1985, 484 ff). With its ability to withstand high temperatures needed for casting and its friability (making it easy to remove once the object is cast), cuttlebones would be an ideal material to be used for casting cores. Since the bones can reach over 30 cm in length, it would be useful as material for small cores as is seen in this chisel. There is no evidence of the use of cuttlebones in the Bronze Age metalworking, but by matching the patterns seen on the inside of the chisel to cuttlefish bone, a new material could be added to the metalworker's inventory.


**Figure 4.7 Chisel with chevrons in socket, Ashmolean Museum, University of Oxford.**

As stated above, it is difficult to determine if a chisel was used as a metalworking tool, or if it was used for exclusively one craft. Chisels found deposited with hammers or other evidence of metal crafting might be assumed to be part of a suite of metalworking tools, however it is dangerous to assume this as the same chisels could be used for other, more ephemeral crafts such as woodworking or leatherworking. Woodworking gouges were found in twelve hoards (see **Table 5.1**) accompanied by both hammers and chisels, thus further blurring the interpretations of the chisels' categorisation into a single craft.

## HAMMERS

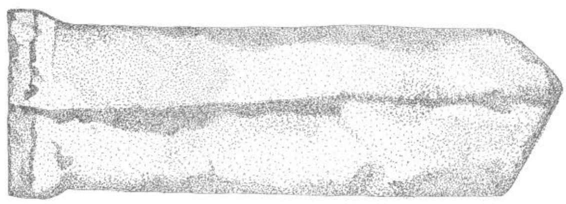
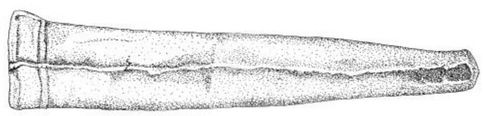
In creating a general typology for European hammers, Jantzen (2008, 362ff) recognised two main types: ones with a peaked face (*dachförmiger Bahn* "roof-shaped") and others with a domed face (*gewölbter Bahn*). Jöckenhovel (1982) recognised six types of German metalworking hammers based on the shape of the heads, ranging from round to rectangular, combined with flat, domed, and peaked faces.

Jöckenhovel's Type 1 is a multipurpose hammer with a square head and slightly rounded face. Types 2 and 3 are similar, with type 3 being larger. However both would have been useful for planishing or working sheet metal. Type 4 is a cross peen hammer, used for sheet metal work or working narrow vessels. Type 5 has a "roof-shaped" face used for peening (stretching metal), and it could have also been used as a stake. Type 6 was described as an embossing hammer and could also have been used as a stake.

While Jöckenhovel's (1982) typology does describe hammer faces and gives interpretations as to function, the types of hammers found in Britain do not directly correspond to the types found on the continent. An early typology for British hammers was developed by Coombs where he recognised two types: Type I that have short, squat bodies that are slightly flared, have collars, and have rectangular or square cross sections. Type II hammers are slender and have parallel sides and a small working edge (Coombs, 1971, 275-276). This typology was based on the limited sample size of 24 hammers available for study at the time.

In Coombs typology Type II hammers were differentiated from Type I based on their size (Coombs, 1971, 275), but it does not take into consideration the function of the hammer. Coombs also felt that these hammers were too light-weight for metalwork. This might be the case if they were used for ferrous metallurgy, however, raising hammers for non-ferrous metalwork can range from 3 ounces to 3 ½ lbs (85 g to 1.5 kg) (Untracht, 1985, 245). This is not inconsistent with the hammer from the Donhead St. Mary's Hoard which weighs 500 g. Consideration should also be given to the weight and balance of the hammer that would be determined by the handle. A longer handle will provide more force to the blow than a shorter one, and the type of wood used is also a factor in considering the total weight.

Because Coombs' typology was based on a small number of hammers, and was based on size rather than function, a new typology was created for British hammers. This thesis recognises five distinct types and one sub-type based on the shape of the faces (**Fig. 4.8**). Here Coombs' Type II (small) hammer would be designated a Type 1a. However, Coombs' Type I hammer, would be distributed between Types 1, 2, 3, and 5 (Type 4 was not discovered in Britain until 1988).

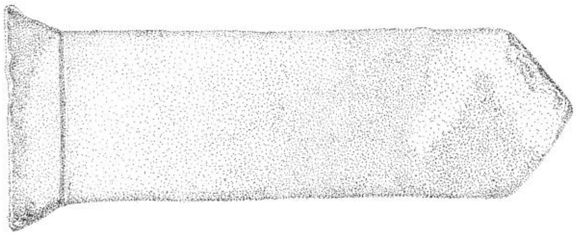
| Hammer Types | | |
|---|---|---|
| **Type 1** | Off-set faceted face<br>Heavy head<br>Square or round cross section |  |
| **Type 1a** | Offset faceted face<br>Long, narrow head<br>Rectangular cross section<br>Tapers toward face |  |

**Type 2**

Faceted face with equal-sized facets

Heavy head

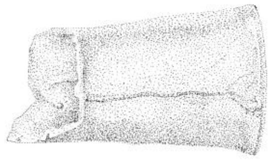
Square cross section



**Type 3**

Curved face

Round cross section



**Type 4**

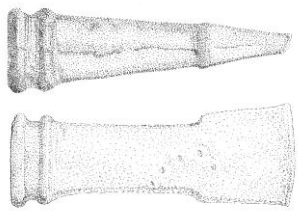
Slanted face

Shoulders

Square or round cross section

Smaller size

Side and dorsal views



**Type 5**

Wedge shaped face

Rectangular cross section

tapering head

Heavy head

Side and dorsal views

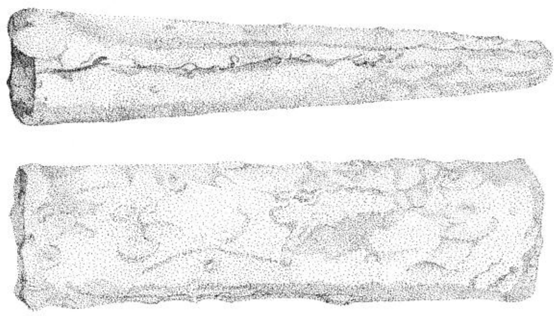


**Figure 4.8 Hammer types. Note: hammers are drawn to scale**

### *TYPE 1*

Type 1 hammers have a profile in which the face is faceted with an obtuse angle of approximately 130°. The apex of the face is offset so that it is divided into two sections, in approximately 2:1. Usually the casting seams do not run along the middle of the sides as they do with socketed axes, but instead they are off-centre and line up with the placement of the apex on the face of the hammer (Example: Bunwell Hoard NWHCM : 1984.1.5:A (**Fig 4.9**)). The hammer is usually square or sub-square with a square mouth; however, variations include hammer heads and sockets that are round.

This is the most common type of hammer found in Bronze Age Britain.


**Figure 4.9 Type 1 hammer, Norfolk Museums & Archaeology Service**

## *TYPE 1A*

Type 1a hammers have a face that resemble Type I, but has a long, narrow, tapering head (Example: Isleham Hoard X20.1 (**Fig 4.10**)). Hammers are usually square or sub-square with square mouths, although there is a variation that has a round mouth and socket such as the hammer in the Burgess Meadow Hoard (AN 1836 p.122-23).


**Figure 4.10 Type 1a hammer, St Edmundsbury Heritage Service**

## *TYPE* 2

Type 2 hammers have a symmetrical peaked face that resembles a modern cross peen hammer. The casting seam on these hammers runs along the middle of the sides aligned with the apex of the face. Hammers are square or sub-square (Example: Donhead St. Mary's Hoard SSWM IC5A.5 (**Fig 4.11**)). Only two examples of this type of hammer have been found.

**Figure 4.11 Type 2 hammer, with kind permission of Salisbury & South Wiltshire Museum ©**

## *TYPE 3*

Type 3 hammers resemble Type 1 or 2, but have a curved face. This could be a worn face of a Type 1 or Type 2 hammer; or it could be by design, in which a face without a distinct facet was desired (Examples: Grays Thurrock Hoard COLEM 02/143 (**Fig 4.12**) and Lakenheath hammer (AN 1927.2662) (**Fig. 4.13**)). If casting seams are still present, they could be used for determining if the hammer was originally a Type 1 or 2, rather than a Type 3.


**Figure 4.12 Type 3 hammer, Colchester Museum**


**Figure 4.13 Type 3 hammer, Ashmolean Museum, University of Oxford.**

### *TYPE 4*

Type 4 hammers have a slanted face. The mouth is circular and narrow with a short neck that widens into shoulders and ends in a wide, chisel-shaped face. This type is predominantly found in Ireland (Ó Faoláin, 2004); however, there is an example from England in the Salisbury Hoard, BM 1999 1.1.225 (**Fig 4.14**).


**Figure 4.14 Type 4 hammer (photo by author © Trustees of the British Museum)**

A variation of this type does not have shoulders, but instead flares out to form a wider face (Example: Lusmagh Hoard, BM 83 2-18.2 (**Fig 4.14**)).


**Figure 4.15 Variation of the Type 4 hammer (photo by author © Trustees of the British Museum)**

## *TYPE 5*

Type 5 hammers resemble large socketed chisels with a tapering head, but have blunt faces (Example: Kilnhurst Hoard, CPMR 1918.7-9.3 (**Fig 4.16**)


**Figure 4.16 Type 5 hammer (photo by author © Trustees of the British Museum, currently at Clifton Park Museum, Rotherham)**

## VARIATIONS

It was seen that in the majority of hammers the mouth was square; however some hammers have round mouths (**Table 4.2).** Offset mouths, forming a diamond-shaped socket in a square hammer head, only occur in Type 1 hammers, and there are only three known examples (Salisbury Hoard: BM 2000 1.1.226, WMS AY 407.2, Kilnhurst Hoard CPM 1918.7-3.2).

| Hammer Type | Percentage of hammers | Proportion with round mouths |
|---|---|---|
| **1** | 58% (41) | 7% (5) |
| **1a** | 20% (14) | 23% (3) |
| **2** | 4% (3) | 0% (0) |
| **3** | 6% (4) | 25% (1) |
| **4** | 8% (6) | 66% (4) |
| **5** | 4% (3) | 33% (1) |

**Table 4.2 Percentages of hammer types (total number of hammers in parentheses)**

The hammers with the offset sockets and one with a five-sided mouth (West Kennet Longbarrow Hoard DVZS 1987.45.1) could be evidence of experimentation with designs to prevent the head from twisting on the haft. There are practical considerations that point to this as being a deliberate variation rather than casting errors. Casting cores for socketed tools are made of a refractory material. If the core is not affixed to the rest of the mould, the core would float on the heavier molten metal and rise up. A free floating core would be difficult to control and the core would not be in the centre, resulting in uneven sides or incomplete castings. Instead, these hammers exhibit an evenly spaced offset core, indicating that the core had been secured in place and had not slipped loose. However, while this might be considered as an evolution in design, dating elements of hoards is problematical and even determining chronological relationships between hoards is difficult to establish (Turner, 1998a, 174).

Another consideration of the offset cores is that the hammer head could be mounted at an angle. Modern hammers with offset faces are designed for sheet-metal work and forging. The 45° angle of the face allows the smith to hammer naturally with the piece positioned at a 90° angle to the anvil so that the smith's knuckles do not hit the anvil (Pers. Comm. Ciaran Benson 2012, smith and tool manufacturer, modern examples of these hammers can be seen on his web page http://hangingpigforge.com/).

Of all the hammers inventoried for this study only one hammer had a loop (Salisbury Hoard BM 2001 6.11). Given that no other hammers have loops, and that the placement of the loop on the side has no practical function, this hammer presents the possibility that it was cast from a modified mould for a socketed axe. The interior of the mould could have been carved deeper and squared-off to widen the axe blade into a square hammer face. The question remains why the loop was left on. However, its presence could be evidence of an experiment, or an adaptation of a mould made from necessity. The general lack of loops on hammers would indicate that hammers were hafted without the use of binding. Since hammers are a percussive tool, and unlike an axe would not occasionally get jammed or stuck into the work surface, there is no need to tie the tool to the haft. This was demonstrated in the experiments conducted in Chapter 6.

A unique tanged hammer from Beechamwell (NWHCM 1949.209) (**Fig. 4.17**) has a profile that is similar to a palstave but without flanges. In order to be hafted, the tang would have been inserted into a handle and secured. The face of the hammer shows considerable burring and deformation, while the tang end does not exhibit any wear. However, the hammer might have also functioned as a short (6 cm) stake with the tang mounted in a supporting surface, such as a tree stump, and the face used as an anvil.


**Figure 4.17 Beechamwell Hammer, Norfolk Museums & Archaeology Service**

Only two hammers have some form of decoration, the hammer from the Taunton Workhouse Hoard (**Fig 4.18**) and a hammer from the Isleham Hoard (**Fig 4.10**). In both cases decoration is minimal. Occasionally hammers will also have collars, however these are usually thicker portions around the mouth of the tool and appear to be more functional than decorative. The lack of decoration could indicate that metalworking tools were not associated with identity in the same way that axe decoration has been used to indicate regional traditions or personal identity.


**Figure 4.18 Decorated hammer (Taunton Workhouse Hoard), The Museum of Somerset, Taunton**

## *TYPOLOGY AND HAMMER FUNCTION*

The nearest modern equivalent to Type 1 hammers is called a *dog-faced hammer*, a type of hammer in which the haft is toward the rear of the head rather than the centre, causing the weight of the head to be forward. The dog-faced hammer also has an offset bevel seen in the facetted face of the Type 1 hammers. This design provides extra weight at the top and front of the tool and the balance can cause the hammer to fall in an arc rather than straight down. This action contributes to the pulling motion needed when working sheet metal. In addition, the hammer works equally well to strike another tool, such as a stamp, chasing tool, or chisel (pers. comm.  Ken Hawley, Kelham Island Museum).

Larger hammers are used for working sheet-metal, or for striking another tool. In the first case the metalworker does not need to see details of the surface being worked. In the latter it is preferable to have a face large enough that the hammer can easily strike the tool without missing or giving a glancing blow. For this kind of work, the smith will look at the blade of the chisel or chasing tool rather than the end where the hammer hits (Untracht, 1985, 126, 245).

Narrow hammers are generally used for fine work such as jewellery making and riveting, where it is necessary to see the object that is being worked (, 1985, 244, 245). The size, shape, and face of Type 1a hammers would indicate that they are designed for fine work, either for small ornaments or jewellery, or for use as a riveting hammer. Maintenance of this type of hammer is crucial for its use. Riveting hammers require a narrow face for spreading the rivet head, and hammers used to work directly on metal surfaces must be kept smooth to prevent marks from the face being transferred to the object. This is especially important when working softer metals such as gold.

Hammers with wedge-shaped faces, such as Type 2 and Type 5 resemble cross peen hammers used for forging sheet-metal (Untracht, 1985, 246, 249). Today this type of hammer is primarily used in the first stages of forging sheet metal where the action of hammering decreases the thickness of the metal while increasing the length (Untracht, 1968, 281) (**Fig 3.2**). The rounded wedge shape of the face facilitates this process by compressing the metal and causing it to spread before and after the face. The repetition of hammering causes the metal to stretch in a direction perpendicular to the longitudinal face of the hammer.

The long narrow head of the Type 5 hammer is also useful for making twisted ribbon torcs. These torcs are forged so that the edges are stretched, forming a dished curve while the whole torc bends in a twisted spiral. This structure is known as an anticlastic curve and is formed using a hammer with a blunt, narrow face on a curved stake. A hardwood branch with an appropriate sized fork, or the curved space between the tines of a large deer antler would both function well as stakes for this work.

## *TOOL INNOVATION AND DEVELOPMENT*

Rather than view tool development as deterministic, moving from simple to complex, changes in tools should be understood as being created to fulfil a function. Tools are designed to accomplish specific tasks. Their development is tied to their purpose and when the need changes, the tool either changes to fulfil that need or falls out of use. From this we can infer changes in metalworking techniques based on the types of tools that are found in assemblages. When bronze hammers appear in the archaeological record of the British Bronze Age, they are in their final form. While there could have been earlier bronze hammers in Britain that no longer survive, the development of the different types of hammers seen from the Later Bronze Age could be the result of tools needed to create new types of metalworking.

The earliest Type 1 hammer was found in the Hambledon Hoard (Winchester). The hoard consists of the hammer and a looped palstave and is consequently dated to the Middle Bronze Age (c. 1400-1150 BC) (Portable_Antiquities_Scheme, 2011). However, the presence of the palstave is a relative indicator since many hoards dated to the Late Bronze Age also contain older objects; The Kilnhurst Hoard is an example of a Late Bronze age hoard that contains both socketed tools and a palstave. With the exception of the Hambledon hammer, the other Type 1 hammers date to c. 1100 BC-c. 800 BC, the same period in which sheet metal cauldrons appear (Gerloff, 1986, 2010). Thus the Type 1 and Type 2 hammers could be seen to have been developed as a response to the need for a medium weight hammer for working sheet metal. The appearance of smaller Type 1a hammers could be related to more precise work for manufacturing ornaments and riveting. While a larger Type 1, 2, or 3 hammers can be used to work metal without needing to hit a precise spot, a smaller hammer is needed when striking small objects such as ornaments or rivet heads. Using a larger hammer for riveting risks bending the rivet to the side, and instead a smaller hammer with a wedge-shaped face spreads the rivet head in one direction and then a second blow given at a right angle to the first not only clinches the rivet tight against the metal, but also widens the rivet evenly to cover the hole.

The earliest Type 1a hammer is found in the Taunton Workhouse Hoard c. 1200-1100 BC (Smith, 1958). While it predates Type 1 hammers, Type 1a hammers could have originally been developed for creating small objects and ornaments. The small size of the face would be ideal for hammering the shanks of bronze pins to a point, and to harden them throughout their length. The narrowness of the hammer would enable the artisan to easily see the object being worked, where a larger hammer would obscure the area of the object being hammered.

## CONCLUSION

In this chapter the categories of tools set out by Untracht (1985) were used to examine metalworking tools of the Bronze Age. Using this system the tools were organised in order to ascertain their function and then compared to those from Bronze Age smiths on the continent and to the nearest modern equivalents.

Tools, such as hammers and anvils were identified and could be cross-referenced to modern counterparts. However, it was difficult to ascertain whether individual chisels were specifically metalworking tools, if they were used for other crafts, or even if they could be associated with a single craft.

In order to organise these tools meaningfully, existing typologies were adopted, or in the case of the hammers, a new one was created in order to recognise the components of a toolkit based specifically on British examples. The typologies used in this thesis stress the importance of function over decoration. The tools were then compared to modern equivalents in order to infer the ways in which they could have been used. This categorisation, combined with examples of contemporary metal objects, provide the beginning steps in recreating the Bronze Age metalsmithing toolkit.

Now that the types of tools found in Britain have been identified, inventoried, and the possibilities of the ways in which they were used explored, the next chapter will commence with a spatial survey of where tools were found. This will be done in order to understand the range of the types of tools used in the British Bronze Age, and if there are regional variations in types and contexts. The chapter will then focus on the examination and analysis of Bronze Age metalworking tools in museum collections. Of particular interest is the identification and cataloguing of wear and evidence of maintenance on tools because it can suggest how the tools were used and how they might have been maintained. This programme of examination will also provide the basis for a schematic system that can be used for a series of experiments utilising replica tools. This examination combined with knowledge of metalsmithing practice will aid in understanding the range of tools necessary for recreating the Bronze Age metalsmithing toolkit.

# Chapter 5 THE ANALYSIS OF TOOLS

> *I asked a blacksmith famous for his superior penknives to tell me the difference between iron and steel.*
>
> *"What's the difference?" he replied. "What is the difference between an oak tree and the willow—they have different natures and one must adapt to them." He did not accept the suggestion that some material absorbed from the fire's charcoal might have something to do with it, and he would not have understood a word of any lecture I could have given him on diffusion, crystal structure, and phase transformations; yet he could make a good knife and I could not.*
>
> (Smith, 1981, 348)

In Chapter 4 the tools found in Bronze Age Britain were organised into functional typologies, the next phase is to examine these tools in order to understand where they were found, how they were used, and how they were made. The methods for this are divided into three main categories: first locating metalworking tools and examining their spatial distribution, secondly examining these tools and recording their characteristics and condition, and thirdly ascertaining the composition of their alloys through chemical analysis.

The artefacts were located using methods described in Chapter 4 and maps were created for the different types. This information will show if there are regional trends in types or depositional practices. Data was gathered by visiting museums where objects were visually examined, measured, and photographed in order to record artefact condition and to catalogue wear and damage that could shed light on how the tools were used. Finally, using criteria described below, a selection of objects were analysed using a portable X-Ray Fluorescence energy-dispersive analyser (pXRF). This was done to gain a broad understanding of the major elements of their composition. This information could also be used to compare the alloys used for the manufacture of other metal objects in order to see if the same alloys are used for tools as for other bronze objects, or if it could indicate regional preferences in alloy choice.

By employing an integrated approach of object examination and compositional analysis combined with the recognition of tool function presented in the previous chapter, insight can be gained into the organisation and use of metalsmithing tools in Bronze Age Britain.

## THE CONTEXT OF TOOLS: SPATIAL EXAMINATION

For the initial process, searches were made for the current locations for objects, using the resources described in Chapter 4. Museums were contacted requesting permission to examine the artefacts. The data gathered for the tools located for this study were compiled along with the spatial coordinates for their findspots, and the results were plotted on a basemap using ESRI ArcGIS, with templates downloaded from Digimap. By examining different parameters, objects and combinations of objects can be examined to see where they were deposited, if there were any regional trends in types of tools, and the conditions under which they were deposited, i.e. single finds or hoards. The result was that while bronze hoards generally occur throughout Britain, with over 6000 hoards identified by the Portable Antiquities Scheme (**Fig. 5.1**), the majority of hoards containing metalworking tools (primarily hammers) were concentrated along the east and south of Britain with an individual outlier located in Inverness (**Fig. 5.2** and **5.3**). This overall geographical patterning could reflect a tradition of depositing metal in this region, but could also reflect a bias in recovery, since the majority of these metal objects are found by detectorists where there is a greater amount of organised activity in the form of rallies in the south and southeast of England (Yates and Bradley, 2010, 43, 72, Barford, 2013). Earlier hoards were most frequently recovered by accident, such as during building or quarrying. Today detectorists are a part of a well-organised and extensive hobby that is active in all counties of England. Whether at rallies, or searching individually, detectorists have developed methods for locating areas where they are more likely to find metal objects (Yates and Bradley, 2010, 70).

Due to the structure of the 1994 Treasure Act Code of Practice, as published by the Portable Antiquities Scheme (PAS), single finds of metal objects that are non-precious do not need to be reported. As a result, reports of single finds of bronze objects are much rarer than that of hoards. If single finds are voluntarily reported, the Portable Antiquities Scheme records the object in the online database and uploads photographs and data such as weight, dimensions, find location, and general information on condition to their website. Afterwards the artefacts are returned to the finder. Therefore, some data is recorded, but this may not reflect the full extent of finds in

Britain. In addition because hoards are larger and more easily located by the detectorists' equipment, there could be a bias towards more hoards being found than single objects.

Another view of the distribution could focus on the geography, where hoards that include metalsmithing tools are found in geographically distinct lowland areas. Such distributions could reflect cultural differences in depositional practices.

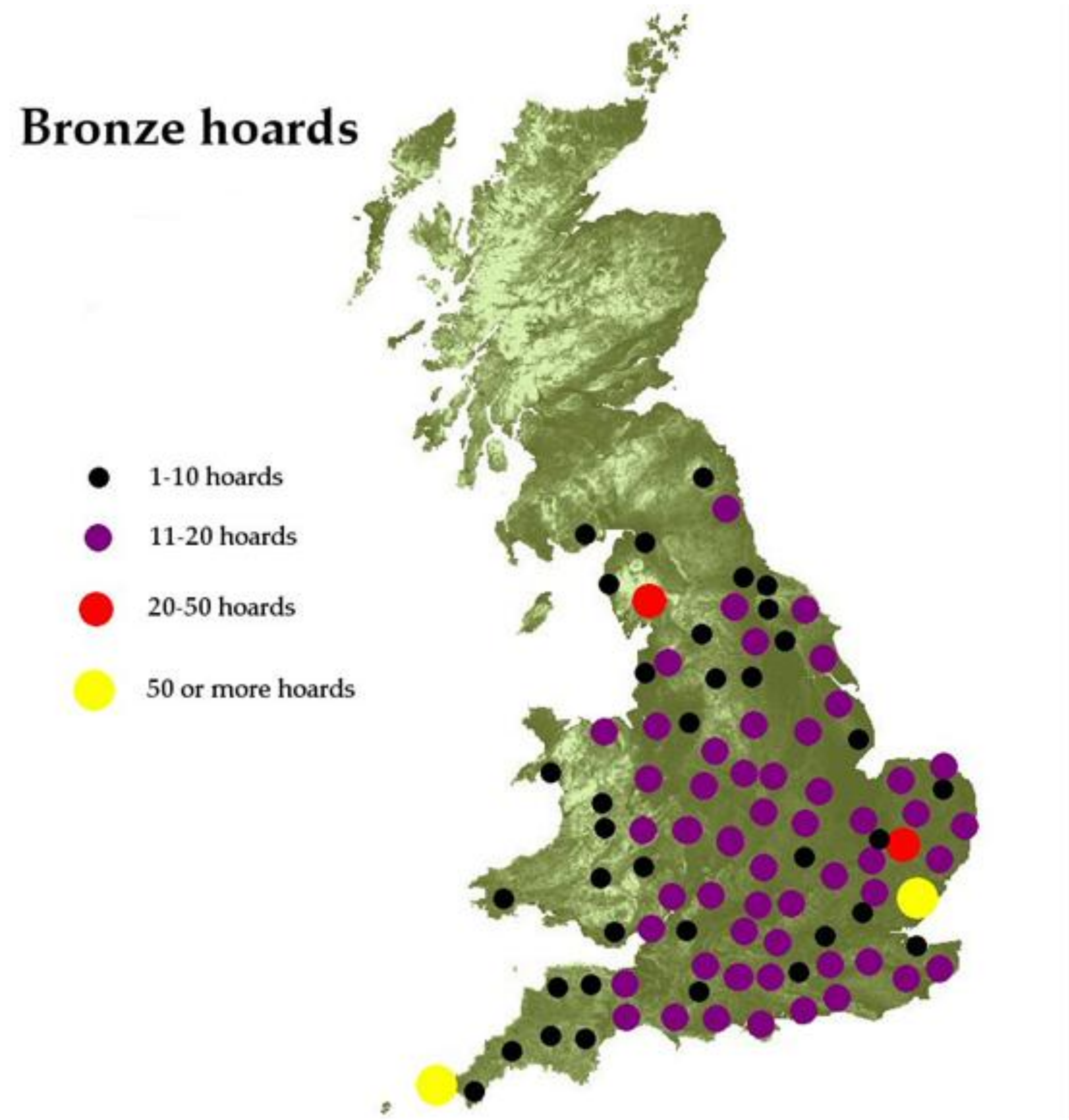



**Figure 5.1 Map of total Bronze Age hoards found in England and Wales as reported to the Portable Antiquities Scheme, (2013 http://finds.org.uk/database/search/map/broadperiod/BRONZE+AGE)**

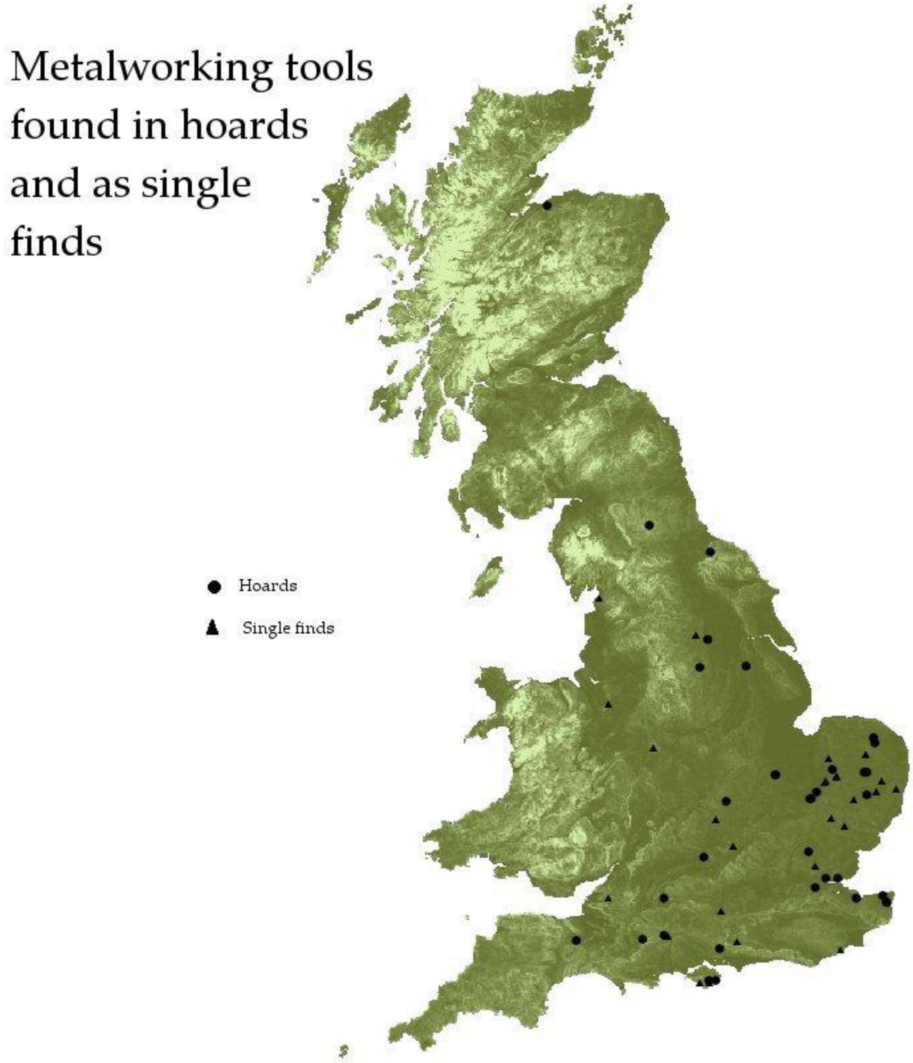



**Figure 5.2 Finds of metalworking tools in Britain**

### *LOCATIONS OF HOARDS WITH METALSMITHING TOOLS AND MATERIALS*

In looking at the locations of hoards that contain metalsmithing tools, it becomes apparent that they fall into a distinct geographic area of Britain. This area is characterised by lowlands, either levels or rolling landscape. Further, the region is a part of Britain in which no metal ores are found. In **Fig 5.3** it can be seen that all the metal ores in Britain are found in the western upland region that includes Wales, Cornwall, and western England.

This division of the landscape means that mining was conducted in a geographically different and distant region of Britain than where tools were deposited in hoards.

Smiths in the southern and eastern lowland region would have been consumers of ore that was either minimally processed, or refined into metal.

The division into two regions creates broad categories, and there are many sub-regions based on differing geography, settlement data, and material culture. Haselgrove warned that it is dangerous to draw too strict a line between the highlands and lowlands, and that an understanding was needed that explained how landscapes were exploited, and how the environment changed over time (Haselgrove, 2002, 49-50). Northover recognised cultural divisions between the highland west and lowland east of Britain, noting that the exact borders varied somewhat over time (Northover, 1982, 98). This division was based upon two distinct alloy types that were in use in Britain during the Late Bronze Age. In the eastern region of England roughly south of the Humber there was an increase in the use of lead in alloys used for casting. This was first seen in ornaments and later it was used more extensively (Northover, 1982, 106).

In the Late Bronze Age, the number and size of metal hoards increased greatly throughout Britain (Bradley 1984, 99). While there are some small hoards found in the Lowlands, the majority of hoards tend to have many more objects than in the Uplands, often containing over 100 objects (Pearce, 1983a, 63, Turner, 1998a, Malim, 2001, Haselgrove, 2002, 65). These frequently included copper ingots and metalworking tools such as hammers and chisels (Barber 2001, 164, Pearce 1983a, 120, 253). Bradley noted that the composition of hoards changed in relation to their distance from the sources of raw materials (Bradley 1998, 129-130). The inclusion of metalworking tools, ingots and casting jets was not a tradition in the Uplands (Burgess and Coombs, 1979, vi, Petts and Gerrard, 2006, 39) . Instead hoards from the Uplands primarily contained palstaves, socketed axes, tools, ornaments, weapons, and non-metal objects such as querns, (Bradley 1998, Ch 3, Bradley 2007, 185, Burgess 1968, 7-23, 28, Burgess and Coombs 1979, vi, Petts and Gerrard 2006, 39).

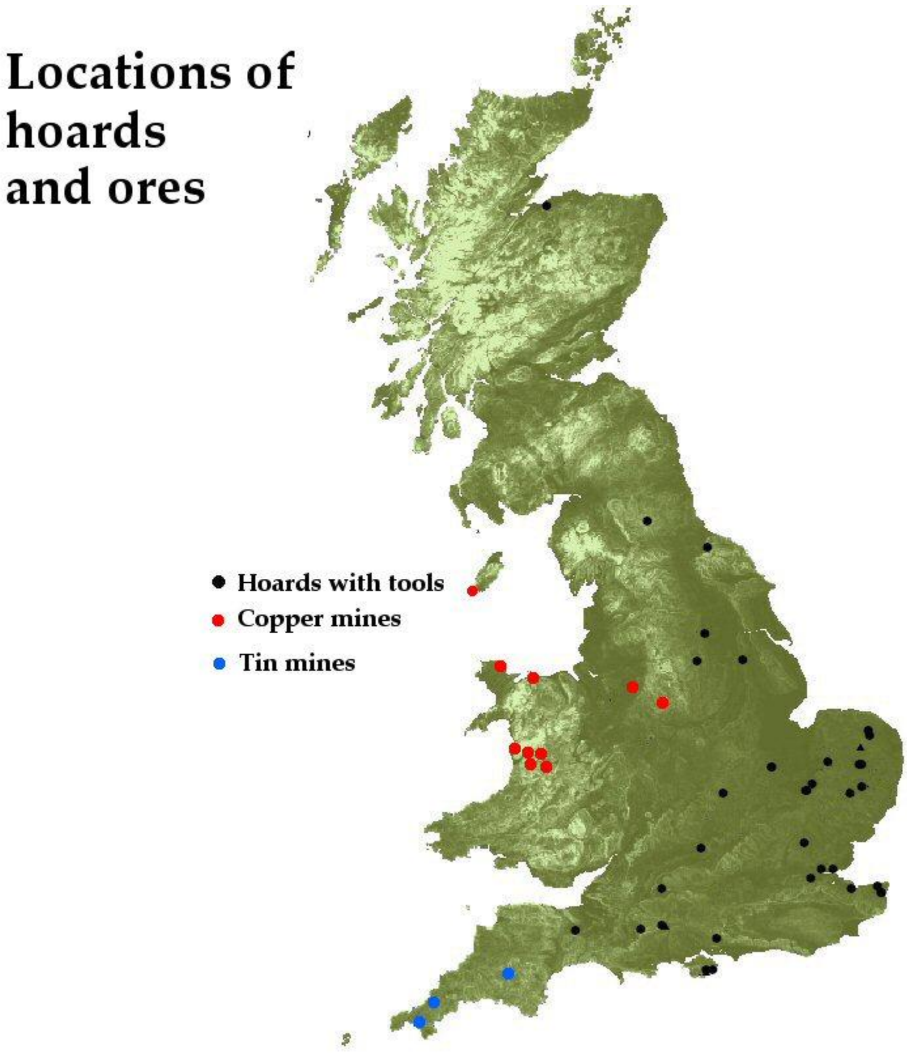



**Figure 5.3 Locations of hoards containing metalsmithing tools and locations of known ore sources in the Bronze Age (ore locations based upon Timberlake, 2001)**

## What are the implications?

Lowland smiths could have been familiar with processes of extracting ore, however as a distant resource, ore could have different cultural values in the lowlands than where it was mined (Fontijn, 2007, 74, Helms 2012, 106). Not only were the hoards deposited in separate geographical zones; hoards also appear to have involved depositions of different types of objects (Fontijn, 2007, 80). Analysis has shown that by the Late Bronze Age recycling was regularly practiced, but also that fresh ore or metal was brought from the highland regions Interpreting this influx of materials is further complicated by bronze objects brought from the continent, presumably as scrap for re-melting (Rowlands, 1976, Muckelroy, 1980, 1981, Northover, 1982, 1989, Needham et al., 1989, 1980).

Rivers would be the main means of transporting ore, metal, or metal objects from the source in the uplands to the lowland regions, and metal from the continent would have come from across the sea. Even though metal would have been recycled, ideas about the origins of metal would have been distant, either in time and space. Perhaps the origins of metal would have been associated with arrival by water, or a knowledge that it came from a mountainous area that is unlike the lowlands of Essex or the rolling landscape of the south of England (Bradley 1988, 251, Figure 1; Helms 1988, 35; Fontijn 2009, 142, 146).

Some form of organisational structure was also necessary for procuring these materials. Either smiths who were knowledgeable about the sources of metal would make long journeys to the source, or the material could have arrived through direct or down the line exchange (Needham, 2000, 1993, Muckelroy, 1980, 1981, Northover, 1982, 1989, Needham et al., 1989, 2001, Kristiansen and Larsson, 2005, 139) (Needham 2000, 2001, 2009; Kristiansen and Larsson 2005, 139). In all of these cases, smiths would be the people who would initiate exchanges and provide the motivation for the acquisition of materials, whether in the form of ore, or refined metal. These hoards also contained ingots of copper, bronze, and alloys of copper and lead. These have been recognised as raw materials for casting, and have been briefly noted that they appear in hoards in the lowland areas (Burgess and Coombs, 1979, Petts and Gerrard, 2006), and were interpreted as a cache of supplies for metalsmiths (Evans 1881, Childe 1930, Burgess 1974). However, there is no explanation as to why ingots appear in the lowland region, but not elsewhere in Britain.

Helms (2012, 111) saw the processes of procurement, refining, creation, and finally deposition as points in a cycle of creation and regeneration, with ritual deposition as a means of assisting the earth's powers to generate ore, thus continuing a cycle in which smiths play integral part. This could be represented by the quantities of ingots found in hoards in this region. Bun ingots that were created by pouring molten metal into a hollow in the ground and then interred in hoards could represent the return of the materials to its source.

The large Lowland hoards containing animal bones and cauldrons imply contributions by many rather than rich individuals, and that they could be the remains of events such as the celebration of treaties (Bradley 1984, 113), marriages (Pearce 1983a, 281), ritual feasting, or other events that would represent the community rather than individuals

(Bradley 1984, 108). Bradley noted that this evidence of feasting showed a connection between high meat consumption and an increased use of metal (Bradley 1984, 163).

As was seen in Chapters 2 and 3, smiths were linked with both tools and metal, forming a relationship in which each element is identified with the other. The connection to ores and resources used by smiths in the lowland regions put the smiths in a position of having knowledge of distant lands, either first-hand or through exchange with those who were more closely connected to the sources of metal, thus increasing their prestige (Helms 1998). The implications of this knowledge, along with the ways in which smiths of the Bronze Age could be connected with the ritual deposition of hoards will be further discussed further in Chapter 7.

The following sections will examine the distribution of metalsmithing tools in Britain, both as part of hoards and individual finds.

### *ANVILS*

Anvils are rare finds and only one has been found as part of a hoard (Inshoch Wood, Inverness) the rest are single finds (**Fig 5.4**). Simple anvils were found in Sussex, Suffolk, and Wiltshire, beaked anvils were found in Somerset and Inverness, and a complex anvil was found in Sutherland. All of these are miniature anvils that can easily be held in the palm of one's hand.

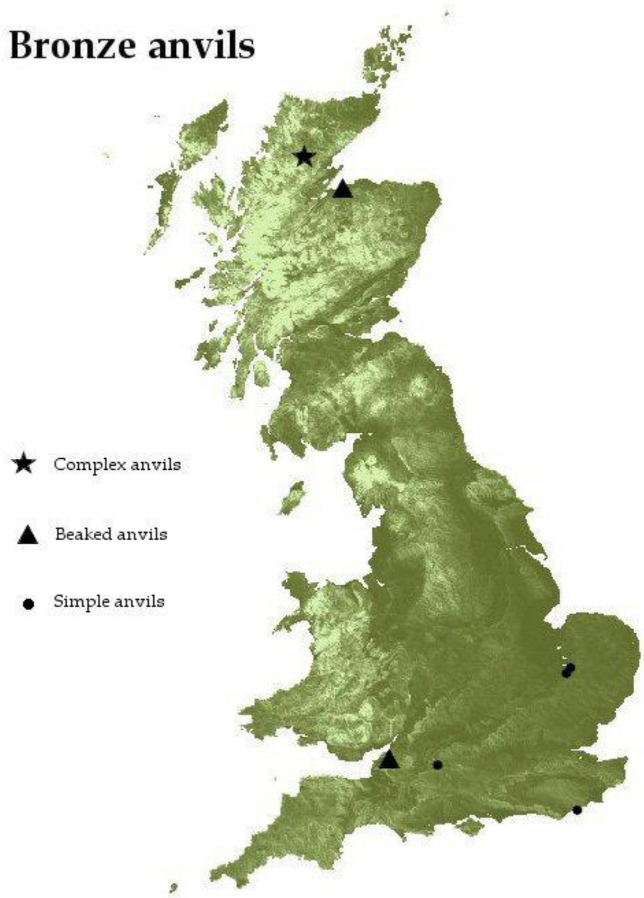



**Figure 5.4 Bronze anvils**

### *CHISELS*

Unlike hammers and anvils which all date to the Later Bronze Age, bronze chisels have been found dating from the Early Bronze Age onwards as both single finds and as part of hoards (Smith, 1959, Burgess, 1968). Chisels have been included in almost every hoard, many having multiple chisels (Turner, 1998a, 177ff). Chisels are found in hoards other that do not contain metalsmithing tools including Broadward and Carps Tongue hoards, and hoards that are categorised as weapon or ornament hoards (Coombs and Bradshaw, 1979, Burgess, 1968, Turner, 1998a, 214, 137-8). Because chisels are found throughout Britain they do not appear to follow the same patterns of hoards containing metalworking tools. Turner questioned if they were included in hoards because they appeared to have been instrumental in destruction of other metal objects such as axes and weapons (1998a, 133). All chisels have the potential to be metalworking tools, however, as discussed in Chapter 4, chisels can cross craft categories and serve multiple purposes. They could be used for metalworking, woodworking, leatherworking, or as miniature axes. Because of this it is difficult to define a chisel as solely as a metalworking tool. Chisels were chosen for inclusion in this study when they were included in a hoard that also included metalsmithing tools, since the context in which these tools are found can also link them with particular activities (Grace, 1996, 220-221). Another consideration was if a chisel appeared robust enough to be used as a metalworking tool. However, as stated in Chapter 4, categorising chisels strictly as metalworking tools can be a dangerous assumption since tools from other crafts, such as gouges are also found in these hoards.

Figure 5.5 shows a map of all the chisels found in England (black dots) contrasted with those chisels that were found as components of metalsmithing tool hoards (yellow dots). While this map is not exhaustive, it does show that chisels are generally distributed across England and that they do not have the restricted deposition pattern as hammers and anvils.

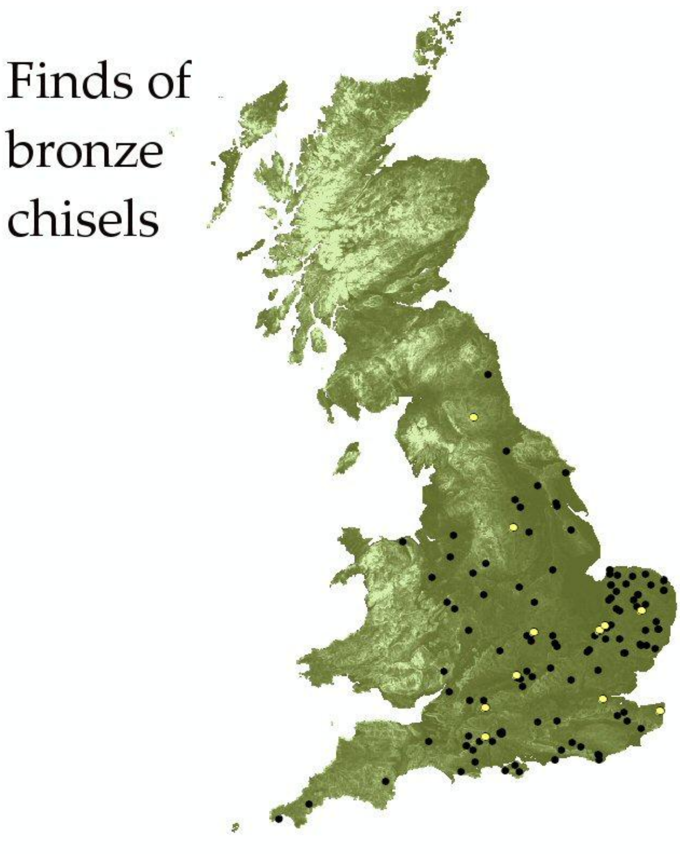



**Figure 5.5 Bronze chisels: Black dots indicate total finds of chisels (data provided by the Portable Antiquities Scheme). Yellow dots indicate chisels located in metalsmithing tool hoards.**

## *HAMMERS*

Hoards containing hammers are found almost exclusively along the east coast of England and along the southern coast into Wessex (**Fig. 5.6**). This closely follows the deposition pattern of metalworking tools seen earlier in Figures 5.2 and 5.3. Individual finds of hammers are also found within this distribution, and include outliers in Cheshire and Lancashire.


**Figure 5.6 Bronze Age hammers**

Type 1 hammers are found in all areas in which hammers are found (**Fig. 5.7**). Type 1a hammers, although fewer in number, are also found within the same range, Type 2 hammers are less common and the four examples have been found in Suffolk, Buckinghamshire, Essex, and Salisbury. Type 3 hammers are also found in the south and East Anglia. Only one example of a Type 4 hammer has been found in England as part of the Salisbury Hoard. The only other examples are found in hoards in Ireland (Ó Faoláin, 2004, 250, 251). Only two Type 5 hammers have been found. One is part of the Kilnhurst Hoard in South Yorkshire, and the other in the Salisbury Hoard.

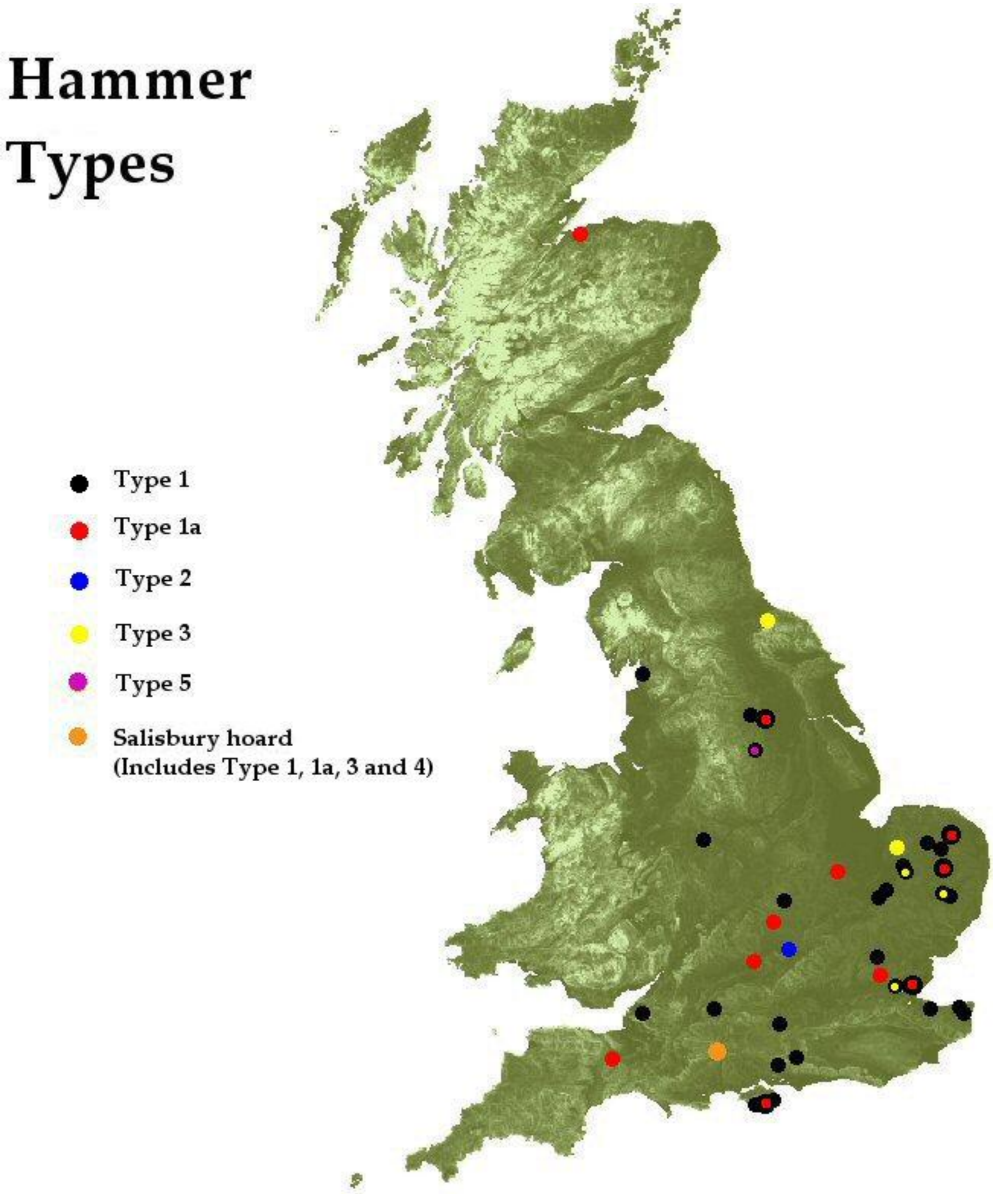



**Figure 5.7 Hammer types**

Both the Isle of Harty Hoard (Kent) and the Isleham Hoard (Essex) have more than one hammer, all of the same type (Type 1 for both hoards). Grays Thurock and Leigh II (Essex), Salisbury (Wiltshire), and Kilnhurst (South Yorkshire) all have more than one hammer, but of different types. All of these hoards have a Type 1 hammer that is accompanied by another type (Grays Thurrock includes Type 3, Kilnhurst Type 5, and

Leigh II Type 1a). The exception is the Salisbury hoard which contains all but a Type 5 hammer (**Fig. 5.8**).

The data suggest that there are no regional differences in the types of hammers found in Britain. Unlike axes, hammers are rarely decorated and variations in hammer design appear to relate to function. Differences in size, shape, and face do not appear to be connected to particular regions. For example, there are no hammers that could be described as a "Wessex type".

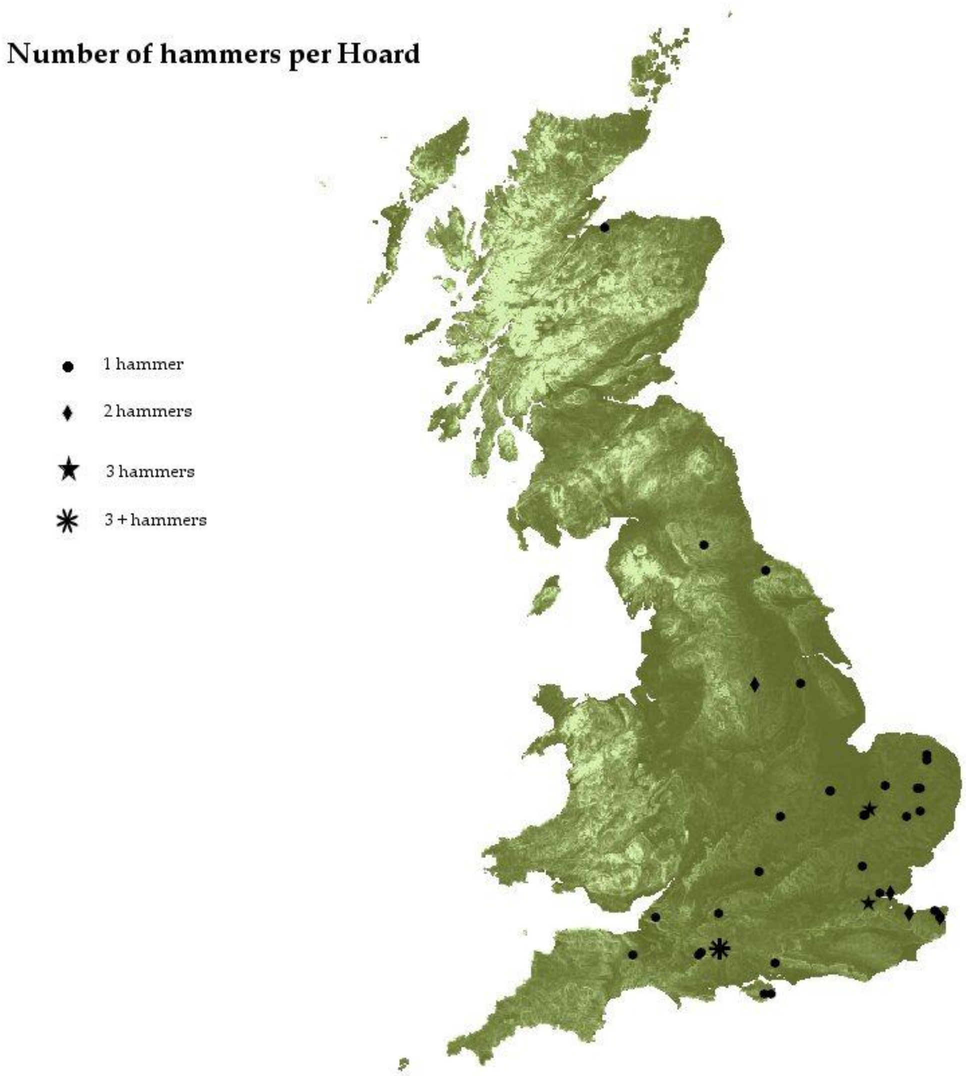



**Figure 5.8 Number of hammers in hoards**

## EXAMINING TOOLS

Care is necessary in identification since, as described in Chapter 4, tools do cross craft categories, and a single tool can serve multiple functions. As a result, only limited interpretation can be made based on the inferred function of a tool. Therefore rather than restricting interpretation based on the examination of a tool's form, this thesis also examines wear since it can be used to gain insight into how a tool was used (Roberts and Ottaway, 2003, 137).

Metalsmithing tools represent an investment of time and effort, and their utility depends on how well they are cared for. Hammers used to strike other tools, such as chasing tools, will develop small dents on their faces. Hammers used directly on metal need to be kept smooth since any damage to the face will be transferred to the surface of the metal being worked. For this reason modern metalworking shops will keep two sets of hammers, one for using to work metal surfaces and another that is used to strike other tools (Untracht, 1985, 244). Chisels also need to be hard and sharp. Chasing and repoussé tools do not necessarily need to be sharp, but they do need to have specific shapes that must be maintained in order for the worked designs to be consistent. Bronze tools used to work on bronze will wear quickly and would need constant maintenance.

For visual analysis, tools were assessed to determine if they had been used or deposited as new objects. In particular, objects were examined for evidence of wear that could have been the result of use. The types of wear include damage incurred during use, such as burring (a distortion where metal is pulled beyond the edge of the tool (Untracht 1985, 640)), or maintenance such as whetting, or if they had been deliberately destroyed, a state that is frequently seen in metal objects that are parts of hoards. While corrosion might inhibit evidence of wear, statements can be made regarding use as to whether a tool saw heavy work before deposition (Roberts and Ottaway, 2003, 127). This programme of examination can provide evidence of how tools were used and to what extent they were used before deposition. This evidence could address questions as to whether tools were included in hoards as scrap for recycling. The wear exhibited on tools can also be quantified and used to compare to replica tools used in experimental work. A combined programme of examination and experimental work can be used to frame questions concerning how tools might have been used, how durable they were, and how evidence of maintenance might be exhibited.

The objects examined in museum collections were measured and weighed, and visually examined both in hand and with a 10x hand lens. Notes were taken for recording wear and maintenance. This information was then entered into a database. Objects were also photographed with a digital camera with macro and super-macro capabilities in order to record fine detail of wear.

An effort was made to examine as many metalworking tools as possible. However, some objects were unavailable because they are in private ownership or lost from museum collections. In some cases museums did not have the capacity to support research and collections were unavailable. The majority of the objects examined were components of hoards; this is in part due to the structure of the Portable Antiquities Scheme that requires reporting of hoards, but not individual objects as described earlier in this chapter. Table 5.1 provides an inventory of the hoards examined and their components. In addition, individual tools were examined at the Wiltshire Heritage Museum in Devizes, Colchester Museum, The British Museum, The Ashmolean Museum, Winchester Museum, and Norwich Castle Museum.

| Hoard | Museum | Categories of objects found in hoards |
|---|---|---|
| **Bunwell Hoard** | Norwich Castle Museum | socketed axe, fragment, scrap bronze, hammer, socketed gouge, socketed knife, ring. |
| **Burgess Meadow Hoard** | Ashmolean Museum | palstave, spearheads, socketed hammer, tanged chisel, hammered rod, thin implement |
| **Carleton Rode Hoard** | Norwich Castle Museum | palstave, socketed axes, winged axe, barbed spearhead fragment, socketed gouges, socketed chisels, tanged gouge, tanged chisel, socketed hammer, socketed mortising chisel, ingots |
| **Cranwich Hoard** | Norwich Castle Museum | hammer, ingot, axe, axe fragment, knife fragment |

| | | |
|---|---|---|
| **Donhead St. Mary's Hoard** | Salisbury and South Wiltshire Museum | bronze mould, socketed axe, palstave, socketed hammer, socketed gouge, bronze ring, lump of bronze, bundle of wire, whetstone |
| **Dowris Hoard** | British Museum | socketed hammer, sword, spear, socketed axe, horn, crotal, cauldron, whetstone |
| **Gilmonby Hoard** | Bowes Museum | socketed axe, spearheads, fragment of a cauldron or bucket, annuli and other ornaments, copper ingot, bronze fragments, pieces of iron |
| **Goldhanger Hoard** | Colchester Museum | Ingot |
| **Grays Thurrock Hoard** | Colchester Museum | socketed hammer, chisel, gouge, sickle, casting debris, ornament, socketed axe, winged axe, cauldron, ingot, weapon |
| **Great Wasketts Hoard** | Southend Museum | Axes, chisels, ingot, ferrule, knife |
| **Hatfield Broad Oak Hoard** | Colchester Museum | bucket, socketed axe, socketed hammer, spearhead, ingot, bugle object |
| **Hevingham Hoard** | Norwich Castle Museum | hammer, socketed axe, axe fragments, bronze mould for socketed axe |
| **Isleham Hoard** | St Edmundsbury Heritage Service | bronze mould, socketed hammer, draw plates, rivet, over 6500 objects |

| | | |
|---|---|---|
| **Inschoch Wood Hoard** | Inverness Museum | spearhead, socketed hammer, anvil |
| **Isle of Harty Hoard** | Ashmolean Museum | socketed hammer, socketed axe, palstave, winged axe, whetstone, small tools/non-ornamental object, ornament, ingot, possible snarling iron, bronze mould, knife |
| **Kilnhurst Hoard** | Clifton Park Museum | Socketed hammer, spear, chisel, axe |
| **Kirkton Hoard** | Isle of Wight County Archaeology and Historic Environment Service | socketed axe, gouge, knife, socketed hammer |
| **Langford Hoard** | Colchester Museum | ingot |
| **Leigh II Hoard** | Southend Museum | socketed hammer, sheet-metal, socketed axe, winged axe, palstave, cauldron, metalworking debris |
| **Lusmagh Hoard** | British Museum | socketed hammer, anvil, graver, trunnion chisel, gouge, punch(?), socketed object, possible rivet snap, polishing stone |
| **Minnis Bay Hoard** | British Museum | socketed hammer, socketed axe, winged axe, cauldron, ornament, scrap metal, ingot, weapon |
| **Minster Hoard** | British Museum | socketed axe, winged axe, palstave, socketed hammer, weapon, decorative work, metalwork debris, ingot |

| | | |
|---|---|---|
| **Northampton Hoard** | Northampton Museum | socketed axe, socketed knife, tanged knife, Carp's Tongue sword, spearhead, casting jet, ingot, socketed hammer, mortising chisel, tanged spearhead, bucket baseplate, vessel fragment. |
| **Roseberry Topping Hoard** | Weston Park Museum | Hammer, sickle, socketed axe, bronze mould for socketed axe, gouge, chisel Objects from the hoard that are now lost include sheet metal, whetstone, 2.5 kg of metal, and a piece of jet. |
| **Salisbury Hoard** | British Museum | Over 535 objects, including hammer, chisel, gouge, punch, anvil, sickle, socketed axe, palstave, flat axe, dagger, knife, chape, ornament, toilet article, miniature shield, miniature cauldron |
| **Swalecliffe Hoard** | British Museum | winged axe, winged adze, socketed axe, sword, socketed hammer, socketed knife, gouge, chisel, chape, ingot fragment. |
| **Taunton Workhouse Hoard** | The Museum of Somerset, Taunton Castle | socketed hammer, palstave, spearhead, axe, razor, sickle, torc, pin, ring |
| **Thorndon Hoard** | British Museum | Awl, axe, gouge, socketed hammer, knife, spear, cremation urn |
| **Vange Hoard** | Southend Museum | socketed hammer, axe, ingot |

| | | |
|---|---|---|
| **Wakering Hoard** | Southend Museum | Axes, sword fragment, ferrule, sheet-metal, ingot, cast metal |
| **West Kennet Hoard** | Wiltshire Heritage Museum | socketed gouge, socketed hammer, chisel/graver |
| **Wickford Hoard** | Southend Museum | Ingot |

**Table 5.1 Hoards examined for this study**

A total of 516 objects were examined, 473 of which were components of the hoards listed above, and 43 were single finds. A database of the tools examined organised by type can be found in Appendix 4, and a full list of all the objects examined is included on the CD Rom accompanying this thesis.

## *RESULTS OF EXAMINATION: THE QUANTIFIED VISUAL ANALYSIS OF WEAR*

The data gathered from the objects were entered into a database using a schematic designed to quantify wear such as scratches, burring, and deformation. The schematic and the quantification of wear on the tools examined can be found in tables 5.2 and 5.3.

### Anvils and drawplates

As described in the previous chapter, bronze anvils found in Britain are small, and some resemble modern jeweller's anvils. While anvils such as those found in the Inshoch Wood Hoard and the Lusmagh Hoard are readily identified as anvils with a flat working surface and beak, others are more difficult to define, especially those that are categorised as a stake. A case could be made for the Beechamwell hammer (**Fig. 4.17**) to be used as a stake, as well.

None of the anvils examined exhibited evidence of wear or maintenance. This could be because they were intended for light use with softer metals such as tin or gold, or if they were used to work bronze, the metal was annealed so that it would be softer than the anvil.

Drawplates have been found incorporated into anvils and as individual objects. In some examples the drawplate consists of a series of notches cut into the sides of the anvil

(**Fig 5.9**) while in others holes are drilled through the anvil, or a solid piece of bronze (**Fig 5.10**).


**Figure 5.9 Notched drawplate Ashmolean Museum, University of Oxford.**


**Figure 5.1 Drawplate, St Edmundsbury Heritage Service**

The only examples of drawplates that are not incorporated into another tool are the three found in the Isleham Hoard (an example of one is shown in Figure 5.10). In a study of wire-making technology, Peter Northover made silicon casts of the interiors of the holes in these drawplates. The casts allowed for the examination of the irregular interior surface and indicated the abraded striations that would appear on wire pulled through the drawplate. The conclusions were that the wire would have a rougher texture than wire drawn in modern steel drawplates (Northover, 1995, 21).

The fine striations observed on the half-round wire that is part of the Donhead St. Mary's Hoard from Salisbury would indicate that the wire had been manufactured using a drawplate such as seen on the anvil in Figure 5.9.

## Chisels

Of the 24 chisels examined (**Table 5.2**), 19 were too corroded to see any evidence of maintenance, although they showed evidence of damage such as dings (H, I, J) or burring (O). Of the corroded (P) chisels, three had been cleaned and had no visible evidence of wear or maintenance.  Of the five chisels showing evidence of wear, one chisel had evidence of rough abrasion parallel to the blade edge (E), another had scratches perpendicular to the blade edge (F), while another was still sharp despite some corrosion. Two of these chisels had burred edges (O). Two other chisels had small dents in the blade (H, I). Two chisels were broken at the tang, just above the trunnion, a flange of metal that would prevent the handle or the smith's hand from sliding down to the blade.

| Wear Type | Chisels |
|---|---|
| **A. Casting seam central** | 4% (1) |
| **B. Flashing/casting seams off-centre** | 0% (0) |
| **C. Rough surface/as cast** | 0% (0) |
| **D. Parallel scratches perpendicular to edge of blade** | 4% (1) |
| **E. Parallel scratches parallel to edge of blade** | 4% (1) |
| **F. Parallel scratches, evenly spaced and unrelated to edge** | 4% (1) |
| **G. Random Scratches** | 0% (0) |
| **H. Dings/small dents on one side of blade** | 8% (2) |
| **I. Dings/small dents on both sides of blade** | 8% (2) |
| **J. Dings/small dents on edge of blade** | 0% (0) |
| **K. Damage to apex of face** | N/A |
| **L. Damage to edge of blade** | 4% (1) |
| **M. Asymmetrical blade** | 0% (0) |
| **N. Deformation or cracks on blade** | 0% (0) |
| **O. Burring** | 8% (2) |
| **P =.Corrosion** | 87% (21) |

**Table 5-2 Chisel wear (total numbers are given in parentheses). A complete table detailing individual objects and the wear they exhibited can be found in Appendix 4**

As with the hammers, the scratches could be the result of maintenance, either to sharpen the chisel blade or restore the shape. Damage to the edge of the blade (L) and burring (O) could have been the result of using the chisel on a hard material, such as bronze or stone.

## Hammers

Of the 43 hammers examined (**Table 5.3**), 16 were too corroded to provide any evidence of wear and one was a fragment. Ten of the hammers had fine parallel abrasions in one or both directions. Of these, nine had fine parallel scratches perpendicular to the edge of the tool (D), while five had similar scratches that were parallel to the edge (E). Three of these hammers had layers of scratches that ran in both directions. An additional ten hammers had fine parallel scratches that did not relate to the edge of the hammer (F). Fifteen hammers exhibited burring (O), four exhibited damage to the apex of their faceted faces (K), three showed damage to the edges of their faces (J), and six had dents on their faces (H, I).

The faces on three of the hammers were substantially distorted, damage that appeared to be the result of heavy use (N). It was noted that while hammers did have varying degrees of flashing remaining along the sides, none had evidence of flashing or any casting seam across the face of the tool, indicating that the all of the hammers had been used, or that at least the faces were cleaned of flashing before deposition.

| Wear Type | Hammers |
|---|---|
| A. Casting seam central | 11% (3) |
| B. Flashing/casting seams off-centre | 48% (13) |
| C. Rough surface/as cast | 3% (1) |
| D. Parallel scratches perpendicular to top edge | 33% (9) |
| E. Parallel scratches parallel to top edge | 18% (5) |
| F. Parallel scratches, evenly spaced, unrelated to edge | 37% (10) |
| G. Random Scratches | 3% (1) |
| H. Dings/small dents on one facet of face | 15% (4) |
| I. Dings/small dents on both facets of face | 15% (4) |
| J. Dings/small dents on edge of face | 11% (3) |
| K. Damage to apex of face | 15% (4) |
| L. Damage to edges of face | 15% (4) |
| M. Asymmetrical face | 15% (4) |
| N. Deformation or cracks on face | 11% (3) |
| O. Burring | 55% (15) |
| P. Corrosion | 90% (30) |

**Table 5-3 Hammers and wear (total number of hammers given in parentheses). A complete table detailing individual objects and the wear they exhibited can be found in Appendix 3**

Of the hammers examined 70% were intact. In hoards that had only one hammer, eleven were complete and four were incomplete. Of the hoards that have more than one hammer, all of them have at least one hammer that is complete. The exceptions are the Kilnhurst Hoard and the Isle of Harty Hoard that have two hammers, both of which are complete.

Of the incomplete hammers, ten had some damage to the mouths, however only three hammers were damaged to the extent that they could not be re-hafted and used. Seven hammers consisted of the face only, however three of those could be questioned as to whether they were actually hammers or a fragment of some other tool. However, since these have been listed in the literature as hammers, they are included in this study.

The parallel scratches (D, E, F) could be attributed to maintenance from sanding or rubbing with a rough stone. This would be done to restore the face to the proper angle, or to remove dings or other damage to the face of the hammer.

Small dings and dents (H, I, J) could be the result of using the hammer for chasing or other activities that involved use with a hard tool, such as a chisel.

Thirteen of the hammers examined exhibited burring (O), a kind of damage that can give indications of the way in which the hammer was used. In the case of hammers, burring is caused by repeatedly hammering a hard surface. The burrs are the result of the direction and angle of the blow and describe how the metal is pushed or pulled along the surface of the hammer face by the direction of the blow. Burring along the top edge of the hammer face indicates the hammer was used to pull the metal towards the smith, while burring on the bottom edge of the face will indicate a pushing action. Coombs (1971, 275) suggested that socketed hammers might also have been mounted vertically and used as stakes, and it is possible that hammers served multiple purposes. The unusual damage to the faces found on two of the hammers in the Isleham Hoard and the tanged hammer from Beechamwell (**Fig. 4.17**) could be the result of their use as stakes, or they could have been modified to facilitate forming a particular shaped object. In this case, the burring would have been caused by the action of another hammer raising or pulling, sheet metal along the edge of the head of the hammer being used as a stake (**Fig. 5.12**).


**Figure 5.12 Burred hammer face, St Edmundsbury Heritage Service**

### *SUMMARY*

The wear exhibited on the tools examined showed that they had been used to varying degrees before deposition. The wear could be studied by comparing the types of wear seen on modern tools. However, this would be evaluating the wear by comparing bronze tools to steel ones. While the appearance of damage such as burring will be similar, in order to accurately assess damage and wear, and more clearly understand how it might have occurred, it is necessary to compare tools composed of similar materials. These tools can then be used in a structured programme of experiments in which different metalworking activities are performed. The resulting wear can then compared to the wear on the original artefacts.

In the next section a selection of tools (one anvil, 13 chisels including a mortising chisel, 12 hammers, a graver, and a punch) will be analysed for their chemical composition, providing information about alloy types that will be used to replicate tools used in the experimental programme in Chapter 6. This data, combined with the spatial analysis given above can also be used to explore the possibility of regional alloy choice.

## ANALYSING TOOLS

In addition to visual analysis, selected objects were analysed for chemical make-up. For this, the widest geographical range and object types were chosen for analysis from the following museums: Inverness, Salisbury and South Wiltshire Museum, Colchester, Wiltshire Heritage Museum in Devizes, Southend Museum, and the Isle of Wight Heritage Museum Service.

The primary method for chemical analysis used for this thesis was undertaken using a NITON XL3t portable X-Ray Fluorescence (pXRF) energy-dispersive analyser. pXRF is an efficient tool for rapid surface analysis and the portability of handheld units make it possible for use in museum settings (Helmig and Jackwerth, 1989, 181).

X-ray fluorescence is a non-destructive method of analysis that is highly useful for understanding the constituent elements of an alloy (Henderson, 2000, 15). The detector in this model is a semiconductor that measures the secondary x-rays, the energy from which is then converted from an analogue signal to digital readings of the electrical pulses caused by the electron exchange. This action is performed simultaneously for each element within the sample within the detector's limits.

The portable unit analyses objects by shooting a narrow beam from a miniature x-ray tube that slightly penetrates the surface of the sample. The depth depends on the density of the material and can range from a few microns to 9.5 mm. The x-ray engages with the elemental components of the object and dislodges an electron from one of the atom's inner orbital shells, thereby causing secondary x-rays to be emitted. In order for the atom to stabilise, another electron from one of the atom's higher energy orbital shells drops into the orbit that had been evacuated, and releases a fluorescent x-ray. The energy of the secondary x-ray is equal to the energetic difference between the two quantum states of the specific electron, and indicates the individual x-ray spectra for each element. The analyser then translates the compiled information, displaying the range and concentrations of elements contained within the sample as a series of peaks. This data is also presented in the form of a list of constituent elements, either as percentages or parts per million (Henderson, 2000, 15, Lutz and Pernicka, 1996, 314, Thermo-Scientific, 2011).

Readings were taken for approximately 30 seconds in order to allow the unit to accurately assess the highest count of elements present in the alloy. This was done in two different modes to quantify refined metals and alloys. The All Alloys mode is a generic calibration for a wide variety of alloy types and provides a general reading for the elements. The Electronics Alloy mode was used to analyse for elements, such as arsenic, that are not included in the All Alloy calibration. The data collected by the unit was then converted into a database that lists the constituent metals of the alloy. The detector has integrated calibration software that corrects for interferences that was run at the beginning of each session.

## *Sampling procedure*

This technique is unfortunately limited to surface analysis and therefore the results are skewed by corrosion product and the possibility of metal migration, enrichment, or depletion resulting from the burial environment, or segregation of metals during casting. In some cases it was possible to take readings from clean surfaces where earlier samples had been taken, but when those circumstances were lacking, readings were taken from the cleanest available surface of the object. The results are therefore considered semi-quantitative and are used to determine the 'basic' alloy type and as a means of comparison between different artefacts.

While the surface analysis taken using XRF cannot be interpreted as an accurate reading of the proportions of metal used in creating an alloy for the reasons stated above, they can indicate the various elements contained within the object giving some indication of a broad alloy group (Helmig and Jackwerth, 1989, 315). By concentrating on those elements that are common to previously published Bronze Age alloys, these tools can be placed within the larger context of Late Bronze Age metalworking alloys. Similar work based on analysis proved valuable for understanding regional differences and changes in alloy choice over time for the British Bronze Age (Dungworth, 1996). For this thesis, the analyses were compared to known Bronze Age alloy groups (Brown and Blin-Stoyle, I959, Hughes, 1979, Tylecote, 1986, Northover, 1989, 119ff). In addition, some of the objects had previously been analysed by other techniques and allowed the current analysis to be compared to the earlier data. While keeping in mind the limitations of surface analysis listed above, databases were constructed concentrating on the elements that constituted the alloys known from the Bronze Age (Cu, Sn, As, Pb, Sb,) in addition to trace elements commonly found (Zn, Fe, Ni).

By taking several readings at various points on the artefact, an average was obtained for use as a mean reading for the entire object. From this, general inferences can be made regarding the presence or absence of elements, along with cautious statements about percentages. Once the analysis was completed, the tools could be more firmly placed within a context that could be used to connect them to regional metalworking traditions. This data also provided a basis for the replication of tools for experimental work.

## RESULTS OF CHEMICAL ANALYSIS

A brief table of analysis is provided below (**Table 5.4**) and complete databases with analysis are provided in Appendix 6, with raw data available on Appendix 1 on the accompanying CD-ROM.

| Object | Accession number | %Cu | %Sn | %Pb | %Sb | %Zn | %Fe | %Ni |
|---|---|---|---|---|---|---|---|---|
| **Anvil** | Inverness | 58.8 | 35.6 | 1.15 | < LOD | 0.32 | 1.22 | 0.40 |
| **Chisel** | Colem 02/118 | 66.3 | 18.6 | 12.7 | 0.1 | 0.4 | 0.6 | < LOD |
| **Chisel** | DZSWS BROOKE 321 | 23.9 | 61.4 | 11.4 | 0.38 | < LOD | 1.51 | < LOD |
| **Chisel** | DZSWS 167 | 83.2 | 15.7 | 0.34 | < LOD | 0.23 | < LOD | < LOD |
| **Chisel** | DZSWS 1984.51 | 27.7 | 57.8 | 11.0 | 0.62 | 0.13 | 1.32 | < LOD |
| **Chisel** | DZSWS 2004.429 | 46.0 | 48.4 | 1.42 | < LOD | 0.16 | < LOD | 0.91 |
| **Chisel** | DZSWS STHEAD 207 | 81.1 | 15.8 | 1.25 | < LOD | 0.22 | 0.21 | < LOD |
| **Chisel** | DZSWS STHEAD 312 | 72.6 | 23.9 | 2.11 | < LOD | 0.23 | 0.16 | 0.11 |
| **Chisel** | SOUMS 276.12 | 60.3 | 21.8 | 16.1 | 0.26 | 0.15 | 0.75 | < LOD |
| **Chisel** | Colem 02/115 | 74.8 | 14.8 | 8.58 | < LOD | 0.27 | 0.48 | < LOD |
| **Chisel** | Colem 02/117 | 80.7 | 15.9 | 1.5 | 0.24 | 0.1 | 0.23 | 0.08 |
| **Chisel** | Colem 02/118 | 66.2 | 18.5 | 12.6 | 0.17 | 0.41 | 0.65 | < LOD |
| **Chisel** | SOUMS 74 | 78.4 | 13.7 | 6.54 | 0.21 | 0.30 | < LOD | 0.47 |
| **Mortising Chisel** | NM 119-29 | 74.7 | 15.9 | 7.11 | | 0.38 | 0.93 | 0.07 |
| **Hammer** | Colem 02/142 | 75.1 | 16.0 | 7.75 | 0.26 | 0.09 | 0.41 | 0.10 |
| **Hammer** | Colem 02/143 | 72.0 | 15.2 | 11.9 | < LOD | 0.08 | 0.32 | 0.09 |
| **Hammer** | Colem 02/144 | 86.7 | 11.9 | 5.24 | < LOD | 0.32 | 0.33 | <LOD |
| **Hammer** | Colem 151.94 | 49.0 | 17.6 | 52.3 | 0.37 | 0.26 | 0.95 | < LOD |
| **Hammer** | Inverness | 54.2 | 42.4 | 0.89 | < LOD | 0.29 | 4.62 | 0.19 |
| **Hammer** | IoW A:2002.26.1 | 56.6 | 20.9 | 16.1 | 0.14 | 0.09 | 9.05 | < LOD |
| **Hammer** | NM 119-28 | 65.3 | 20.5 | 12.6 | | 0.28 | 0.53 | |
| **Hammer** | SSWM IC5A.5 | 61.4 | 29.8 | 8.70 | 0.13 | 0.18 | 0.43 | |
| **Hammer** | DZSWS 1987.45.1 | 39.1 | 57.8 | 0.20 | 0.20 | 0.18 | 1.04 | 0.36 |
| **Hammer** | SOUMS 276.55 | 70.9 | 24.7 | 3.01 | 0.15 | 0.26 | 0.19 | 0.11 |
| **Hammer** | SOUMS 276.56 | 59.0 | 27.3 | 12.0 | 0.38 | 0.21 | 0.20 | 0.11 |
| **Hammer** | SOUMS 72 | 86.1 | 10.2 | 2.5 | 0.15 | 0.28 | 0.22 | 0.34 |
| **Graver** | DZSWS 1987.45.2 | 24.7 | 71.5 | 0.18 | 0.15 | 0.13 | 1.94 | < LOD |
| **Punch** | DZSWS 1982.39 | 34.3 | 41.7 | 1.33 | < LOD | 0.27 | 1.80 | 0.13 |

**Table 5.2 pXRF analysis of tools (<LOD indicates that the element was below the limit of detection for the analyser)**

Tin levels were unusually elevated in the readings, often with averages in excess of 15-20% with one chisel having 48% and an exceptional graver (DZSWS 1987.45.2) with 71.5% tin on its surface. The tools from the Inshoch Wood hoard also have high percentages of tin, as does the hammer from the West Kennet Long Barrow Hoard, along with chisels from the same area. This could be due to various factors including the migration of tin or the depletion of copper as part of the corrosion process (Tylecote, 1979, 351, Scott, 1991, 43-44, Robbiola et al., 1998). These readings point to the cautions that must be taken into account when using surface readings, even with objects that are analysed using a cleaned surface.  Another, and most plausible explanation, is that the high surface levels of tin and lead are the result of inverse segregation that occurred when casting. When casting bronze, the moulds must be heated in order to prevent cracking, or in a worst-case scenario, a small explosion. Tin and lead have a much lower melting temperature than copper, and so when the molten alloy comes in contact with the heated inner surface of the mould, the metals with the lower melting temperatures next to the warmer surface, solidifying last, creating a concentration on the surface of the cast object (Scott, 1991, 5-6, Bassett, 2008, 277). This was demonstrated by the author when analyses of objects cast into moulds were compared to ingots cast onto a flat surface and analysed using pXRF (data available in CD Appendix 3). Those objects cast in ceramic moulds had elevated levels of tin on some surfaces, noting that external surfaces of the faces of the hammers had been altered through use. Readings were also taken from areas where the surface was removed and two hammers were cut in half in order to take readings from interior surfaces. When compared to identical alloys cast into an open ingot mould, the alloy exhibited a consistent mixture of copper, tin, and lead throughout. Further experiments could be conducted that would measure the temperature of the interior of moulds prior to casting in order to quantify the percentage of enriched elements of the alloy at the surface. This could shed light on casting practices and the treatment of moulds in antiquity.

The result of high concentrations of tin on the surface gives the object a silvery colour that could make it stand out from other tools. However, because the tin is a soft metal, this coating would not endure on the tool's working surface and would wear off. The result would be that after long use, the tin would be worn and the bronze below exposed. While this might be considered a disadvantage, the variability of tin on a tool's surface could also highlight the history of the tool's use and enhance its value as an object that had been well used in the creation of other objects (Meeks 1986).

From the analysis of the chisels and hammers, it was found that lead was incorporated in the alloy to varying degrees. While acknowledging the limitations described above, the results showed that the lead content of hammers in south and south-east Britain ranged from 13% to 16%, with an average of 14%. Other tools (chisels, and gouges) contained a lower percentage of lead with an average of 9%. In comparison, hammers from the south-west had an average of 5% lead. However, the lead content in other tools in Wessex ranged from 0.3% to 17% and could be divided into two categories: a low lead alloy with an average of 1% lead, and a high lead alloy with an average of 11% lead (excluding the graver which had the exceptionally high lead content of 17%).

Brown and Blin-Stoyle divided Late Bronze Age objects into two broad groups based on the lead content of the alloy, stating that lead could be used an index for determining the character of Late Bronze Age artefacts (Brown and Blin-Stoyle, I959, 195). While Brown and Blin-Stoyle did not provide raw data, they did publish information about two major alloy groups: Group I with less than 1% lead and variable quantities of nickel, and Group II with greater than 1% lead and less than 0.5% nickel. In comparing their spectrographic analysis of objects analysed by Brown and Blin-Stoyle to the same objects analysed for this study, those from south-eastern Britain fall into Group II, with higher lead content. Objects from Devon, Norfolk, Oxford, Isle of Wight, and Somerset were composed of Group I alloys (Brown and Blin-Stoyle 1959, 200-208). Of the data they gathered, four hammers from hoards were analysed (Burgess Meadow, Oxfordshire; Reach Fen, Cambridgeshire; Thorndon, Suffolk; and Minster, Kent). All of these hammers were listed by them as being Type II despite the rest of the objects in the Burgess Meadow hoard being defined as Type I.

Tylecote used spectrographic analysis to determine lead content and found that most copper ores contained 0.02 to 0.8 lead, and that levels of 5% lead were added to alloys in south-eastern Britain (Tylecote, 1968, 53). Burgess also equated the increase in the use of lead with the rise in these hoards in the south-east, and increased regionalisation in metalworking styles (Burgess, 1968b). He noted that the division of these styles coincided with the use of lead as an addition to bronze alloys, with leaded bronzes in the south especially concentrated in the Thames River Valley, Cambridgeshire, and East Anglia (defined as the Wilburton Complex), with fewer incidents of this tradition farther north and west (Burgess, 1974, 208, Burgess, 1968b, Fig. 8).

In the 1980's studies employing analysis of lead isotopes in copper alloy objects were used to provenance metals to sources where the copper was originally mined, with the goal of understanding circulation patterns of metal objects (Stos-Gale, 1989). In their study of Bronze Age metal objects Rohl and Needham warned that isotope signatures are not the same as chemical composition, however employing isotope analysis with other analytical techniques could be used to complement each other and clarify interpretations (Rohl and Needham, 1998, 176 ff).

Their analysis of the lead isotopes found in Late Bronze Age British metal showed that there were changes in metal sources, and that raw materials were both mined in Britain, and imported from the continent. While some lead appears to have already been in the alloy due to recycling older objects, increased amounts greater than 2% appear to be the result of freshly added lead (Rohl and Needham, 1998, 180).

The division noted by both Brown and Blin-Stoyle and Burgess is reflected in the data obtained in this study using the pXRF. The reasons for the regional differences in leaded alloys could range from a continental influence of metalworking in the southeast that brought a tradition of including lead in bronze alloys. This is in contrast with the more conservative traditions of the rest of Britain at that time (Burgess, 1974, 208). The division also reflects the spatial analysis given above, where the areas in which leaded alloys are used coincide with greater concentrations of hoards that contain metalsmithing tools. Metalworking tools are found in lesser quantities outside this region, and the data could tentatively relate metalworking traditions of alloy choice with depositional practices of including tools in hoards.

Both Tylecote and Northover noted that the use of lead varied between types of objects in Britain. The percentages varied with smaller amounts of lead used for swords and weapons and greater amounts for ornaments and thin-walled objects, with tools falling in the middle range (Tylecote, 1968, 48, Northover, 1982, 90-91, Northover, 1987, 226). In addition lead can also increase the weight of the finished object (Northover, 1982).

Adding lead to bronze alloys has the advantage of lowering the melting temperature of the alloy and making the alloy easier to pour. The addition of 2% lead helps to increase fluidity in casting, but larger percentages reduces the strength and ductility of the alloy (Brown and Blin-Stoyle, I959, 193). Having a less viscous alloy would be advantageous for pouring into complex moulds such as those containing cores for sockets. However, adding more than 20% lead results in a brittle alloy. In experimental work, it was observed that a molten alloy containing 5-7% lead flowed more easily and did not affect the performance of the tools that were cast.

## EXAMINING THE TOOLS

In this chapter, Bronze Age metalworking tools were identified and located through literature and online searches in order that they could be examined and analysed.

Spatial analysis showed that hammers and metalworking tools other than chisels have a pattern of distribution in Britain that is located predominantly in the lowland areas of the east and south of England. This is in distinct contrast to the regions in which ore is found. This regional division also coincides with the chemical analysis that showed that leaded bronzes were preferred by smiths working in the southeast of England.

While anvils tend to be single finds, hammers and other tools are mostly found as components of hoards. However, chisels present a problem in their abundance and their ability to cross craft categories. Their presence in a hoard might indicate a craft other than metalsmithing, such as woodworking or leatherworking. Since gouges are also found in hoards, questions could be addressed as to whether this indicates the presence of multiple artisans or if a metalsmith worked in different media to complete an object, e.g. making a bronze knife with a wooden handle.

The second half of this chapter examined Bronze Age metalsmithing tools in museum collections. These examinations showed that hammers were usually found intact. Almost all of them showed evidence of use and the majority were in remarkably good condition. Many appeared to have been maintained, with evidence of sanding, whetting, or some other activity that produced fine parallel scratches. However some tools had been used to the point of being heavily burred or even deformed. None of the hammers appeared to have been deliberately destroyed in the same way that axes are treated. Although some of the hammers were broken, none of the sockets were crushed flat, or jammed with other metal objects as is seen with other socketed tools. Chisels also appeared to have been used, with some showing evidence of abrasion.

Anvils and drawplates provide the third category of metalsmithing tools that are found in any quantity. These tools, while they can be put into typologies, are highly individual, and no two found in Britain are identical.

Chemical analysis utilising a pXRF showed that alloys used for socketed tools is the same leaded alloy as used for other cast objects during the Late Bronze Age. This could indicate that lead was added in order to improve the alloy's pourability into complex socketed moulds while not impairing the durability of the object. However, the quantity of lead used in alloys was not consistent across Britain and could indicate regional traditions regarding alloy choice.

Together Chapters 4 and 5 have begun to organise the metalsmithing tools found in the British Bronze Age. By combining typologies based on function with inventories of the tools found in Britain, a clearer view of the range of metalworking tools in the Bronze Age in Britain begins to emerge. The quantitative recording of wear also provided information about tool use and can enhance the understanding of the way tools were used in antiquity. The chemical analysis presented here combined with analyses done by others gives us an understanding of the range of alloys used for manufacturing bronze tools.

The examination of tools and the range of types combined with chemical analysis that provided information about alloy proportions and regional preferences now provide us with a template and recipe for duplicating tools examined in museum collections.

When the types of metalsmithing tools listed in this chapter and Chapter 4 are compared to those categorised by Untracht, it can be seen that there is a limited scope of tools remaining from the Bronze Age in Britain. This limitation will be addressed in Chapter 7.

In Chapter 6 replica tools based on the data gathered in this chapter and Chapter 4 will be used for a programme of experimental work that will address questions regarding tool function, durability, and processes of metalworking. Once the experiments have been concluded, the wear on the replica tools can then be compared to the wear observed on the museum objects that was presented in this chapter. This will be done to determine if the tools could have been used in similar ways.

# Chapter 6 THE EXPERIMENTAL PROGRAMME

> *The smith also sitting by the anvil, the vapour of the fire wasteth his flesh, and he fighteth with the heat of the furnace: the noise of the hammer and the anvil is ever in his ears, and his eyes look still upon the pattern of the thing that he maketh; he setteth his mind to finish his work, and watcheth to polish it perfectly:*
>
> *Ecclesiastics, 38:28*
> *1769 Oxford King James Bible*
> *"Authorized Version"*

In *Archaeology by Experiment,* (1973) John Coles outlined the ways in which programs of experimental work are valuable assets to the study of archaeology. Experiments can be used to test hypotheses pertaining to early technology, in that models can be made, tested, and assessed against original archaeological artefacts (Mathieu and Meyer, 2002, 75). The experiments conducted for this thesis were designed with specific goals to assess the ways in which metalsmithing tools could be used. These assessments included recording their durability, performance, and after the experiments were completed, the wear on the replica tools was compared to those in museum collections. Earlier studies have made use of experimental archaeology to assess performance of bronze axes (Mathieu, 2002b, 3), and to examine wear on replica axes in order to make comparisons to wear on archaeological artefacts (Roberts and Ottaway, 2003). Such studies provide information that would be otherwise impossible to obtain from solely examining original artefacts.

While experiments might answer specific questions they can also prompt more questions, inferences, and interpretations leading to the recognition of variables that previously had not been considered (Mathieu, 2002b, Mathieu and Meyer, 2002, 75-77). This is especially true when considering the context of the experiment. When archaeological experiments are conducted in the field instead of the laboratory, the context is less controlled, leaving new opportunities for variables that might not have been possible in the lab environment (Mathieu and Meyer, 2002, 76, Outram, 2008, 2).

In addition to answering questions about tool performance and wear, experimental archaeology can also give those involved in the experiment a physical understanding of those activities (Mathieu and Meyer, 2002, 75). This is especially relevant when the activity is not one would normally experience in the modern world (Outram, 2008, 2). Because of this, it is important that the participants have a certain amount of practical experience in the activity (Coles, 1973, 16, Outram, 2008, 3). In these experiments, working with experienced artisans meant that tool performance and use were discussed in a way that not only compared them to modern tools that were regularly used by participants, but they also suggested ways in which tools could be modified or have other uses. The professional advice and observations of the participants was invaluable and provided further insights into Bronze Age metalworking.

However, as valuable as these experiments might be, they should not be considered replicas of past behaviour or exactly re-enacting the ways in which metalworking was performed. There is always an element of uncertainty with results in that there can be no absolute proof of how specific tasks were performed in prehistory (Coles, 1973, 17). While we cannot replicate the exact experience of a Bronze Age metalsmith or recreate acts that occurred in the distant past, archaeological experiments can lead to an understanding of factors such as tool use, spatial needs, the functional properties of the tools, and limitations of materials (Coles, 1973, 13, Reynolds, 1999, 157-8, Mathieu, 2002a, 3, Outram, 2008, 2, Jackson, 2009, 401). In addition, the understanding of the physical skills involved and experiencing non-discursive learning is valuable (Bleed, 2008, 157, Kuijpers, 2013, 138).

Material specifications can inform us of physical properties including hardness, limitations, or melting point, but it is only by performing experiments that we can understand how materials could function. In order to be able to conduct experiments with meaningful results, objects should be constructed as closely as possible to the original archaeological artefacts (Coles, 1973, 16). For these experiments tools were created using measurements and alloy "recipes" that were based on artefacts examined in museum collections and recorded in the previous chapters. This programme primarily focused on replicating the types of hammers and chisels found in Bronze Age contexts in order to understand the way in which tools could have been used in metalworking tasks. Tools were assessed for their ability to perform tasks, their durability (i.e., the length of time that a tool functioned before necessary maintenance such as sharpening or restoring the shape), and to document the processes of the metalsmithing tasks. After they were used, the tools were examined for wear in order to compare them to museum specimens.

## EARLY EXPERIMENTS IN METALWORKING

Examples of the earliest metalworking techniques were recreated through experiments designed to replicate the copper sheet metal work made by Native Americans during the Middle to Late Archaic periods (3000-1000 BC).

Cushing (1894) and Willoughby (1903) both did experimental work replicating Native American sheet metal work using stone tools to beat out nuggets of native copper. In his experiments, Cushing employed different types of stone hammers, beginning with a rougher grained granite or quartzite, and then smoothing by both hammering and rolling the metal with a cobble of diorite polished in the shape of a celt. In order to cut designs into the sheet copper, Cushing used a technique called *pressure grooving*, or *line embossing*. For this he made different chisels of antler, buckthorn wood, and bone. The metal was placed on layers of leather and the tools were used to push a groove into the metal that would create a ridged design on the reverse. The metal was then turned over and the raised lines were ground down with a piece of sandstone. This technique enabled early metalsmiths to make intricately cut designs (Cushing, 1894, 100-104).

In his experiment Willoughby made a replica of a domed copper earring using water worn stone cobbles to flatten the nugget. The edges were cut using a sharp flint and then the metal was smoothed with stones. The earring was formed into a dome by pressing the sheet metal into a carved wooden form with a bone tool (Willoughby, 1903, 55-56). Both men maintained the copper's ductility by frequently annealing the metal in a charcoal fire.

Oddy (1977) experimented with manufacturing gold wire, drawing on medieval documents and close examination of prehistoric wire and tools. In these he experimented with hammering out lengths of gold and then twisting the metal until it was a solid strand. These were then pulled through a drawplate, making the helical seams nearly invisible.

Although some of these experiments sought to replicate American metalwork, the goal of the experiments described above was to duplicate objects using techniques available in the period of study. The same technology could be applied to gold, copper, and bronze sheet metal work in Britain.

## GOALS

In addition to a working knowledge of tools such as hammers and chisels, these experiments present the opportunity to define the different ways of using metalworking tools to create metal objects. As noted in Chapters 4 and 5, no metalsmithing workshops have been found, and that the range of tools necessary to complete metalworking tasks is limited to those tools that have been either accidentally lost, or deliberately interred in hoards. As explained earlier, many tools would be lost to deterioration, or were for one reason or another, not included in depositions. These experiments will not only highlight the metalsmithing processes, but will shed light on the other materials and tools required to complete a task.

## METHODS

For this study, tools were replicated using data gathered from museum objects. This, combined with the study of tool typology, provided for the creation of tools that could be duplicated as closely as possible to the original tools used in the Bronze Age. Alloys were blended using information from literary sources (Tylecote, 1962, Brown and Blin-Stoyle, I959) and the pXRF analysis described in the previous chapter.

Nine replicas of Type 1 and Type 2 hammers, and a replica of the anvil found in the Inshoch Wood Hoard were cast using an alloy of copper (85%), tin (10%), and lead (5%). They were cast in refractory moulds that were composed of two layers. The outer layer was made of a mixture of one part commercially prepared earthenware clay, one part beach sand, and one-half part chopped straw and sawdust. The inner layer was made of one part earthenware clay, one part fine grog, and one part fine sand. To this pulped mixture organic material (sawdust), crushed charcoal, and ash was added. Cores for the hammers were made with the same refractory material with the addition of 50% wheat germ by volume. The addition of wheat germ was from a 'recipe' used by Dr. Holger Lönze of Umha Aois. This mixture results in more friable refractory material and facilitates the removal of cores from the cast bronzes. The 'recipes' for the refractory materials used in these experiments can be found in Appendix 2.

Initial casting was carried out at the foundry of the University of Sheffield under the supervision of Stuart Bater, and Philip Staton, heads of Materials Processing for the

Department of Materials Science and Engineering. In addition to casting in modern facilities, primitive casting was conducted at the 2012 Umha Aois annual symposium in Dingle, Ireland. The facilitators at Umha Aois, Niall O'Neill, Dr. Holger Lönze, and Pádraig Mc Goran, are professional bronze smiths and sculptors who are dedicated to researching Bronze Age metallurgical technology. Other tasks were completed at Heeley City Farm in Sheffield, where a small furnace was built and maintained for experimental work.

A set of small chisels for chasing designs and carving were also forged from 10% tin bronze bar stock. These were forged using a steel hammer and a replica Type 1 hammer in order to compare performance.

Hammers were hafted using angled branches of cherry, willow, and oak. Initially the haft was secured with rawhide; however it was found that if the section of the handle that went into the socket was carved to fit exactly, and then a small strip of leather was wrapped around it before it was inserted, the hammer head was secure and needed no additional binding. Because these hammers would be used for activities that involved repeated percussion, balance and weight are concerns when considering the amount of time and energy involved in various metalworking tasks (Untracht, 1968, 97). With this consideration, handles were made using different woods, with different lengths and thicknesses (**Fig. 6.1**). It was found that an oval handle was more comfortable than a round one, and as expected a longer, heavier handle provided stronger blows. Modern hammers for general use have handles of hardwoods such as oak or hickory, woods that are strong, heavy, and durable. However for lighter work, such as planishing and chasing, a lighter, more slender handle made of fruitwood provides more bounce and requires less arm movement (McCreight, 1982, 16). It should be noted that wooden handles are rarely found from the Bronze Age, and that the design of the handles is as much an experiment as the bronze portions of the tools.


**Figure 6.1 Different styles of handles left to right: cherry, oak, cherry, willow, willow**

Before they were used, the tools were measured, photographed and impressions were taken of working surfaces using a resin based polyform clay. The impressions were created to supplement to the photographs, providing a permanent three-dimensional record of all the tools. The polyform clay was chosen because of its ability to take detail; it does not shrink, and is durable after firing. The clay was rolled out to provide a smooth surface and the tools were then pressed into the clay. In the case of chisels, impressions were made of all four sides and the edges. The clay was then baked at 130° C for 15 minutes, after which the product hardened. Its ease of use made it ideal for making three-dimensional records of tools in the field.

## THE EXPERIMENTS

The tools were used to accomplish specific tasks.

- Removing flashing from cast objects
- Sharpening/putting an edge on an axe
- Using bronze tools to carve a stone mould
- Forging bronze
- Breaking up metal objects
- Forming a sheet metal object
- Planishing a sheet metal object
- Working chased decoration
- Maintaining tools

The experiments were designed to replicate metalworking tasks as closely as possible to the way in which they would have been practised in the Bronze Age. To that end, tasks were recorded for the length of time they were performed, including noting times for natural interruptions such as annealing. The tasks were designed as a unit where damage and wear would be recorded as they accumulated for each task. Methods, such as recording changes to object or tools at intervals could be seen as counterproductive since these tasks were unlikely to have been performed with constant interruptions. Interruptions would also make it difficult to record the length of time to complete a task, since rhythm is a part of metalworking, especially when forming sheet metal or carving stone.

After use, the tools were examined for signs of wear. This included taking measurements, photographing, and taking impressions. Changes to the tools were then quantified using the schematic described in Chapter 4. The wear could then be compared to tools in museum collections. However, while their use in Bronze Age contexts could be inferred by the resemblance of the wear marks, it cannot be assumed that they are definitely the result of specific actions (Roberts and Ottaway, 2003, 123). Hammers and chisels can serve a variety of purposes, and although modern tools often have specialised functions we cannot assume that this was the case in prehistory. The results of the wear analysis is presented in the individual experiments below, in addition a full table of the wear using the schematic from the previous chapter is included in the wear-use database in Appendix 3.

### *EXPERIMENT 1: REMOVING FLASHING*

Hammer A1 (a replica of a Type 1 hammer) and chisel 7 (a replica of a Type 2 chisel) were used to break flashing from several palstaves as soon as they were removed from the mould and reasonably cooled. The hammer was chosen primarily for its wide, flat face that would connect well with the chisel. The chisel has a flat sharp edge that would efficiently and quickly cut through the metal. These were supported on a large, flat piece of flint that was used as an anvil. The action was performed quickly and easily with no change to hammer or chisel.

### *EXPERIMENT 2: SHARPENING AN AXE*

Hammer A2 (**Fig. 6.4**), a replica Type 1 hammer, was used to restore the edge on a bronze axe that was cast from 10% tin bronze. The axe was being used to carve a cedar log when it hit a nail beneath the bark, gouging a large notch in the edge (**Fig. 6.2**). The blade was ground back so that it had a curve similar to its shape before the damage. The resulting edge was 3mm thick, with the blade 95.2 mm wide from tip to tip, and 35.4 mm from the centre of the blade to the stop-ridge. Impressions were taken of the hammer and the axe before work commenced. The hammer was used as cast, without hardening and was hafted with a heavy oak handle for durability. A large bronze bushing was used as an anvil. The experiment was performed by Mr. Pádraig Mc Goran, a professional sculptor and metalsmith.

After ten minutes of hammering, the axe was annealed in a charcoal fire. After an additional 45 minutes, the blade was hardened to the point where it would need to be annealed a second time. At this point it was decided that the blade was thin enough that a second annealing would be counterproductive. The thickness of the blade was 0.9 mm, and the width of the blade was 99 mm with a measurement of 38 mm from the stop ridge to the edge of the blade. The axe was finished with light sanding and stropping with leather. Once sharpened the axe was used for the rest of the week without further need of sharpening (**Fig. 6.3**).

The hammer was initially chosen because of the wide flat face of the lower facet, however, the work was done using the top facet of the hammer's face. When he tried using the lower facet, Mr. Mc Goran felt that he had less control over the process of beating out the metal.

It was noted that the hammer did not rebound in the same manner as a steel hammer does when hammering sheet bronze. In addition, unlike a steel hammer, the bronze hammer left no marks on the edge of the axe. The metal was planished in the process, leaving a relatively smooth bevel leading to the edge.

Overall, the hammer performed excellently. However the apex of the face was reduced to a flattened band across the centre, and the circumference of the face was deformed and burred (**Fig. 6.5**). Mr. Mc Goran is left handed. It was noted that the wear on the hammer was on the opposite side of the hammer used by the author, who is right handed, indicating that wear might suggest handedness (**Fig. 6.23**).

**Figure 6.2 Axe before sharpening**

**Figure 6.3Axe after sharpening**


**Figure 6.4 Hammer A2 before use**


**Figure 6.5 Hammer A2 after use**

## *EXPERIMENT 3: CARVING A STONE MOULD*

Hammer A2 and two chisels (0 and 2) were used to carve a piece of purple limestone from Co Kerry, Ireland (**Fig. 6.6**). The work was performed by Mr. Pádraig Mc Goran. Chisel 0 was shaped by Mr. Mc Goran into a blade 4mm thick with a bevel beginning 4 mm before the point (**Fig. 6.8**). This created a tool with a wide point that was used to remove stone quickly that could also cut interior corners. Chisel 2 has a wide, flat blade 1.6 mm thick by 16 mm wide. The blade is blunt and was used for shaping the flat portions of the mould. Both of the chisels needed to be sharpened frequently. Hammer A2 is a replica Type 1 hammer and was used for the experiment because its broad face would ensure that the hammer would hit the butt of the chisel without concern for missing the target.

**Figure 6.6 Stone mould**

While carving the mould, the shaft of the chisels tended to bend into an "S" shape. These were hammered to restore their shape and in the process, the metal was hardened, requiring less straightening as the work progressed.

**Figure 6.7 Carving the mould**

Both the top and lower bevel of the hammer face were used in the process. Mr. Mc Goran used the hammer according to how he wished to direct the blow. The balance of the hammer contributed to the concentration of the blows with the two angles of the face facilitating the direction of the blows. In this way he could use the faces of the hammer to either push the chisel forward or direct it back towards himself (**Fig. 6.7**).

The task was completed in five hours, and it was noted that using modern tungsten carbide chisels, the task would have been completed in twenty minutes. Before use, chisel 0 was 113 mm long and chisel 2 was 111 mm long with a blade that was 17.6 x 1.5 mm. After the work was completed, chisel 0 was 110 mm long, and chisel 2 was 108 mm long with a blade that was 16 x 1.6 mm (**Fig 6.8**).

Before work the face of hammer A2 was 35 mm wide, with an upper facet of 17 mm and a lower facet of 23 mm. After the work was completed, the hammer was 36 mm wide with a bevelled face that measured 21 mm for the upper facet and 22 mm for the lower (**Fig. 6.9**).


**Figure 6.8 Chisels before and after use**

**Figure 6.9 Face of hammer A2 after use**

## *EXPERIMENT 4: FORGING*

### Forging bar stock

Hammer F1, a replica Type 2 hammer was used to forge 8 mm diameter 10% tin bronze bar stock into a square shape for making chisels. The hammer initially measured 72 mm long with a face measuring 28.5 mm diameter and was chosen for its wedge-shaped face that resembles modern forging hammers. The hammer was used as cast, with no prior hardening. Work was done continuously for one hour and nine pieces were forged with a combined length of 756 mm. After 20 minutes of use, the top edge had a distinct burr and the bottom edge was rounded. After one hour, the hammer had rippled distortion marks above and below the apex of the face, which was now flattened (**Fig. 6.10**).


**Figure 6.10 Hammer F1 before and after forging. Note flattened apex after use**

**Forging chisel blades**

Hammer A1 was used to forge a blade on an 8 mm 10% tin bronze bar. The hammer was chosen for its larger size and flat facet of its face. Work was done for 45 minutes (not including time taken for annealing). The hammer was used as cast, but the metal hardened as it was used (**Fig. 6.11**). Within ten minutes of work, the hammer performed as well as a steel hammer. After work was completed, the hammer face was smoothly rounded, with no apex (**Fig.6.12**). It was noted that the finish on the chisel was smoother, without the dents normally seen when using a steel hammer (**Fig. 6.13**).


**Figure 6.11 Hammer A1 before use**


**Figure 6.12 Hammer A1 after use with chisel**


**Figure 6.13 Note that the shafts of the two chisels on the left, and the chisel fifth from the left were forged with a steel hammer**

## *EXPERIMENT 5: BREAKING METAL OBJECTS*

Chisel 7 and hammer A1 were used to cut an ingot of tin 10 mm thick and 12mm wide. Hammer A1 is a replica Type 1 hammer and is suited for using with chisels since the wide flat face makes it easier to hit the target of the slender end of the chisel. Chisel 7 was used previously in Experiment 1 and was used in this experiment for its suitability for cutting. The task took 45 seconds. There was slight burring on the end of the chisel and dings on the face of the hammer.

Hammer A1 and chisel 7 was also used to remove casting jets and pouring cups from cast objects. The most efficient means to accomplish this was to remove the upper portion of the ceramic mould, exposing the casting cup and jets, as soon as possible after casting. The exposed metal was given a quick blow, causing the exposed metal to snap off from the cast piece. The rest of the mould was then removed and the cast object allowed to cool. When it was not feasible to remove the casting jets immediately, the cast object was briefly reheated to a cherry red in the charcoal fire and broken while still hot. This technique was also used to remove the casting jets from palstaves cast in bronze moulds (**Fig. 6.25**).

While it is not possible to melt bronze in a normal charcoal fire, knowledge of working at the proper temperatures is essential. During the time it is hot; bronze is brittle and can be easily snapped. However once it has cooled, bronze becomes malleable (annealed) and rather than breaking, the object will bend. Hot forging of bronze is possible; however the process requires optimally controlled conditions and a tin content that is less than 7% or above 20 to 25%. However, even within these parameters, impurities in the alloy can have a detrimental effect that would not be problematic if the alloy was worked cold (Cuthbertson, 1960, 397-8).

## *EXPERIMENT 6: FORMING*

A 6 inch diameter sheet of 10% tin bronze 0.7 mm thick was annealed in a charcoal fire and hammer A2 was used to form the bronze into a bowl (**Fig. 6.14**). Because the experiment began with metal that was already in sheet form, it was unnecessary to use a Type 2 hammer. Hammer A2 is a replica Type 1 hammer and was selected because it would gently deform the metal, but not compress it unevenly as a Type 2 hammer would. The resulting surface would be mottled with regular bumps rather than deep ridges.

A large rounded cobble of diorite was used as a stake. The stone was set into the ground and the work was done in a seated position with legs crossed around the base of the stone. In this position it was easier to hammer using the upper facet of the face.

The sheet metal was annealed frequently. This was done when the metal became stiff, the hammer rebounded, and the sound of the hammering changed from a dull thud to a more ringing sound. The piece was buried in charcoal and allowed to heat for ten minutes. It was quenched and work resumed.

**Figure 6.14 Hammer A2 and stone anvil**

The hammer was attached to the handle by carving the portion of the haft that fit inside the socket to fit snugly. It was secured by a strip of leather inside the socket as described earlier. As the hammer was used, the leather compressed. The result was that the head began to twist while hammering and the edge of the face produced some distinctive dents in the surface of the bowl. The leather was replaced, the work resumed, and the dents were hammered and reduced to fine folds. It was noted that having a square socket as seen in hammers described in Chapter 4 would be an improvement that would reduce twisting. The basic form of the bowl was completed after four hours' work (**Fig. 6.15**); however this included the time taken for annealing and re-hafting the hammer.

**Figure 6.15 Bottom surface of bowl after forming**

## *EXPERIMENT 7: PLANISHING*

As was seen in experiment 2, bronze is affected differently when worked with bronze hammers than with steel, and that the use of a bronze hammer produces a more planished surface than steel hammers. However, the surface did have a mottled texture and it was decided to planish the bowl to create a smoother surface. In order to provide a softer surface, a stake with a rounded, convex head was carved from a heavy branch of cherry wood. The head of the stake measures 61 mm in diameter with a height of the curve at 9 mm. This was mounted in a small tree stump that provided a stable platform for the stake (**Fig. 6.16**).

**Figure 6.16 Stake made of cherry branch secured in tree stump along with hammer and bowl**

A smaller hammer, C1, a replica Type 1 hammer was used lightly. The purpose of this was to even out any irregularities caused by the heavier hammer and to provide a smoother surface for polishing and chasing. The edge of the bowl was ground down to an even height using rough gritstone. The bowl was then hammered lightly, starting at the centre of the base and working in a spiral towards the rim. After the work was done, there was no change to the hammer face. The bowl still had a fine hammered texture that could have been removed by further hammering with a wooden mallet. However, it was decided to polish the metal with no further smoothing of the metal. After planishing the bowl measured 38 mm high by 103 mm diameter (**Fig. 6.17**).


**Figure 6.17 Planished bowl**

## *EXPERIMENT 8: DECORATING*

Before decorating the bowl with a chased design, the surface was polished using leather and fine sand that was slightly dampened. It was noted that because the metal oxidised when it was annealed and that the oxidation was not removed prior to resuming hammering, that there was a heavy layer of firescale embedded in the surface. In addition, the annealing process produced a surface enriched in copper, giving the metal a more reddish appearance.

A simple design using punched dots, and vertical and diagonal lines was chosen as a pattern for the decoration. This would closely imitate designs seen on lunulae and other objects. The bowl was supported on the stake used previously and fine guide-lines were inscribed on the surface prior to chasing. An antler tine was initially chosen as a chisel for punching the dot design, however, rather than making an impression, the point of the antler collapsed. Chisel 5 was then modified to have a sharper point and used for the punched dot design (**Fig. 6.18**). Hammer C1 was used as a chasing hammer. Its flat face would connect well with the narrow ends of the chisels used as chasing tools; and its handle that is narrower near the head was designed to spring back while hammering resulting in a continuous bouncing action.

A line was chased below the punched dots with chisel 0. This was the same tool used in Experiment 3 (carving a stone mould). The chisel cut a very fine line and at times easily slid along the surface while the line was chased. However control was difficult, and results would be better if the bowl was supported with pitch, rather than being able to move freely on the stake. Chisels 0, 3, and 9 were chosen to chase in the design (**Fig. 6.18**). Modern workshops will have several chasing tools in order to create a wide variety of designs on objects. This effect can also be seen on a bracelet fragment that was part of the Leigh II hoard (SOUMS 276/107) where different sized tools were used to create the design (**Fig. 6.19**).


**Figure 6.18 Chisels selected as chasing tools: From left to right 0, 9, 3, 5**


**Figure 6.19 Bracelet fragment decorated with chasing using different sized tools**

Chisel 0 produced a thin, sketchy design, while chisels 3 (2.2 mm wide) and 9 (2.7 mm wide) made more substantial lines (**Fig. 6.20**). Chisel 3 is more rounded and so had to be rotated or moved forward to complete a line, where chisel 9, being rounded but with a gentler curve, could produce a complete line by rotating while being hammered. This produced a more even line. From Figure 6.20 it can be seen that different shapes and widths of chisels produce a variety of lines with varying qualities.


**Figure 6.20  Chasing on bowl produced by chisels 0, 3, and 9**

During chasing, both facets of the hammer face were used. The hammer face shows fine dings from hitting the butt of the chisel with an almost mottled texture on the upper facet (**Fig. 6.21**).

**Figure 6.21 Hammer C1 after chasing**

## *EXPERIMENT 9: MAINTENANCE*

During the course of the experiments the hammers sustained noticeable wear, including burring, dents, and loss of the apex. After having been used in Experiment 8, the face of hammer C1 was restored using a piece of coarse Derbyshire gritstone. The process took five minutes for the upper facet and ten minutes for the lower facet, which had sustained more damage. Afterwards the hammer was ground against a piece of finer gritstone for two minutes in a direction perpendicular to the first grinding. The grinding left fine parallel horizontal scratches, although some deeper vertical scratches remain from the coarser stone (**Fig. 6.22**).

**Figure 6.22 Hammer C1 after maintenance**

As noted earlier there appeared to be a difference in the hammer used by the author and that of Mr Mc Gorhan, and the possibility was considered that it could be related to handedness (the author is right handed and Mr Mc Gorhan is left handed). The wear on hammers F2 used by the author in the forging experiment, and hammer A2 used by Mr Mc Gorhan for sharpening the axe exhibit wear on opposite sides (**Fig. 6.23**). Hammer F2 has a distinct widening and flattening of the apex on the proper right (PR, the hammer's right); with the apex measuring 3.9 mm on the PR and 5.9 on the proper left (PL). On hammer A2 the apex measures 7.2 mm on the PL and 8.6 on the PR and is noticeably flatter on that side. In addition the upper PR of the face is stretched upwards and towards the left, causing burring and distortion of the hammer head. This is noticeable when compared to the hammer face before use (**Fig 6.4**).While this is a small sample and cannot be considered conclusive, it is interesting to note and could be a focus for further study. In the following chapter hammers examined in museums will be compared for similar wear.

**Figure 6.23 Evidence of handedness in wear: F2 on the left shows more wear on the proper left of the hammer, where the apex is wider and more flattened than on the proper right. On hammer A2 The upper proper right of the hammer is flattened and distorted (including burring) and the apex is more flattened on that side. Compare these to Figs 6.10 and 6.4 that show the hammers before use.**

## *OTHER EXPERIMENTAL WORK*

In addition to the experiments above, experimental casting events were held at Heeley City Farm in Sheffield, and at Umha Aois in Ireland. For these events the author made a set of bag bellows, crucibles and moulds (**Fig. 6.24**). A variety of furnaces were constructed and used including short shaft furnaces, and bowl furnaces that were either heated from above or below. In addition to making and using the bronze tools in the experiments, other tools were created as needed, such as tongs that were made of bent willow lashed together and dipped in clay slip. All of these objects, except for the moulds and crucibles, were made of ephemeral material and so their use in the Bronze Age must be inferred from the need for them in the manufacturing process.

**Figure 6.24 Bellows and crucibles**

While participating at Umha Aois, a two part bronze mould for a small palstave was made available for casting. It was found that the mould was very efficient for quickly casting bronze objects. The mould was supported in a sand pit and required no binding other than the pressure of the sand. No release agent was necessary. The poured metal cooled quickly and the mould was opened immediately to prevent the shrinking metal from binding in the mould. The mould was set up again soon after the cast palstave was removed and was ready for another pour. The pouring cup was removed with a sharp hammer blow while the palstave was still hot. A small amount of flashing (approximately 1 mm thick) was produced by the weight of the metal in the mould pushing the valves apart (**Fig. 6.25**).

**Figure 6.25 Bronze mould with palstave (mould courtesy of Billy Mag Fhloinn)**

## DISCUSSION

Experiments such as the ones presented here address questions regarding how specific metalworking tasks could have been accomplished in a way that provides physical evidence of craft practices. These can then be compared to the evidence seen in museum objects. In these experiments the tools worked satisfactorily, and in some cases exceeded expectations. The bronze hammer used to sharpen the axe not only performed well, but provided a smooth surface in the process, thus negating the need for additional planishing. The main difference observed between the bronze tools and modern steel tools was that the tasks took longer to perform, and in the case of chisels required more frequent maintenance. While Bronze Age metalsmiths would not have been able to make this comparison, it is a consideration when addressing issues such as the change from using bronze tools to iron ones.

As noted in the experiments specific tools were chosen for their design. Wide, flat hammer faces are best for striking chisels because the butt of the chisel does not need to be seen and the larger face ensures that the blow will not miss the chisel. Forging hammers are better designed for stretching metal more quickly as was seen in Figure 3.2.

Handles are also as much a consideration as faces when considering function and design. The heavy oak handles provided weight and leverage when used to perform tasks that required substantial deformation of metal. Handles made of lighter, more flexible hardwoods provided a bouncier tool that could be used for continuous lighter work. This allowed for extended periods of hammering without tiring. It was also seen how different chisels could be used for different effects in decoration, and that chisels with wide flat faces were well suited for cutting metal.

By using these tools in experimental work, improved knowledge of tool function and the organisation of the metalworker's craft emerged. Observations of wear indicated whether a hammer was used directly on a metal object, such as in experiments 2, 4, and 6; where the apex of the hammer faces had flattened and the edges were burred. In experiments 3 and 8, hammers were used to strike chisels, resulting in faces that were covered with small dents. Details of the quantified wear analysis of both the tools used in these experiments and objects examined in museum collections are available in detail in Appendix 3.

The chisels were also affected by work in that the butts were burred and the tool became shorter because of repeated sharpening. It was noted that some chisels developed an “S” shaped curve and had to be hammered straight again. Other observations of wear led to unforeseen information, such as the possibility of handedness. The results of these observations of the wear exhibited on these tools can now be compared to museum objects using the same schematic used in Chapter 5.

Additional information was gained about chisels and performance in experiment 8, where the effects of different chisel widths and arcs produced different qualities of chased lines. This could be a consideration when examining tools and objects in museum collections in that widths and characteristics of engraved or chased lines on objects could be used to infer the size and shape of the tool used to create them, and comparing them to known tools. Thus the experimental work here provides a basis for further research into metalsmithing practices.

The experimental programme presented here made connections between metalsmithing tools, techniques, and finished metal objects. Because of these experiments, some of the materials missing from the archaeological record were more easily recognised. While there might have been a limited suite of tools used in the Bronze Age, it is logical to assume that if a metal object exists in the Bronze Age, then the tools and materials necessary for its manufacture must also have existed. The missing tools could have been lost to deterioration, poor preservation, or the possibility that the bronze versions of tools became outmoded with the advent of iron tools, and were recycled. In order to provide a more complete picture of Bronze Age metalsmithing, a system is proposed that will organise the various aspects of the craft that will aid in the recognition of missing elements. The following chapter will develop this system in which the complete set of tools and materials needed for metalsmithing can be organised. This will not only shed light on what other tools might be missing from an assemblage, but it also could be used to work backwards from a finished metal object to infer what tools and materials were required for its manufacture.

In Chapter 7 a system will be presented whereby the activities associated with metalsmithing can be organised so that tools can be placed in the sequence of different metalworking processes.

The following chapter will also examine the contexts from which metalsmithing tools have been found in order to ascertain why particular tools are present while others are missing. Because the majority of tools available from the Bronze Age were found in hoards (Chapter 5), it appears that only certain types of tools were chosen for deposition and their inclusion in hoards could indicate references to specific metalworking practices. With the recognition of limited types of tools found in hoards and the theoretical frameworks set out in Chapters 2 and 3, the significance of these Bronze Age tools can be explored.

# Chapter 7 METALSMITHING TOOLS IN PRACTICE AND HOARDS

> *...the base of the whole structure of technological institutions is the individual technologist, with various motives, driven by glimpses of beauty or of profit or of service to mankind; sometimes a far-out discoverer, sometimes a repetitive craftsman, sometimes a deviser of ways of making more, sometimes an entrepreneur who seeks the inventions of others which he can adapt to perceivable needs; but he is always human and always contributing to the intellectual and social changes.*
>
> *~ Cyril Stanley Smith (1981, 348)*

The objective of this thesis was to reassemble the tools of the Bronze Age metalsmith based on an understanding of the craft and how it was practiced. This study began with an examination of the smith and metalsmithing tools through literary sources, and went on to establish a theoretical framework to understand the symbolic meaning of tools and the significance of smiths and metals in the British Bronze Age. This was followed by a study of the types of metalsmithing tools found in Britain from Bronze Age contexts and an examination of these tools in museum collections. These examinations focussed on wear, design, and chemical composition, and provided insight into metalsmithing practices and regional variation of tool deposition. This research also supplied the data needed to manufacture replica tools for use in a series of experiments that were conducted in order to understand tool use and performance. Using the tools in experiments answered questions about their role in metalsmithing, leading to the observation that many tools were missing from the archaeological record.

This chapter will interrogate the data generated in the previous chapters and use Untracht's classification system as a basis for creating a system wherein Bronze Age metalsmithing tools can be functionally organised. This, combined with data from the experimental programme and the formulation of a method for understanding metalsmithing practices, will result in a system in which metalsmithing tools and processes can be more readily identified in the archaeological record.

Finally the context of Bronze Age metalsmithing tools will be examined. A detailed knowledge of tool function and metalworking processes gives another dimension in the way in which hoards can be interpreted. Since the majority of tools are from hoards, questions will be addressed such as why only certain tools are included, if the combinations of tools indicate specific metalworking tasks, if their condition has any significance, and how we might use metalsmithing tools to interpret the role of smiths or metalworking practices in the British Bronze Age.

## WHAT TOOLS DO WE HAVE AND WHAT IS MISSING?

The tool types listed in Chapter 4 were recognised as having specific functions for tasks including forging sheet metal, forming metal objects, setting rivets, decorating metal objects, and sharpening edged tools.

Because the presence of metal objects implies the existence of the tools and materials necessary to create them, the third column of the table includes those tools that would be assumed to have existed in the Bronze Age. Table 7.1 expands upon the table presented in Chapter 4 to include those tools that are missing from the archaeological record of the British Bronze Age. Most of the missing objects are made of substances that would deteriorate in the archaeological record. Wooden or antler mallets are needed because they can be used to shape metal without compressing it. For example, once sheet metal has been forged to the desired shape and thickness, wooden tools such as mallets or bossing hammers (a type of rounded mallet) can be used to shape the metal into a curve without thinning the metal as much as a metal hammer would. They can also be used to work harden metal after it has been annealed without deforming the metal. Swages, mandrels, and large anvils could also be made of hardwood that would be lost to the archaeological record. Tools that would have been made from bronze, such as pliers, stamps, and dies have not yet been found, and it could be that these types of tools were recycled at the end of their useful life.

| Type of tool | Examples found in Bronze Age assemblages | Examples *not* found in Bronze Age assemblages |
|---|---|---|
| **striking / percussive impact tools** | hammers | Wooden or antler mallets |
| **indirect striking percussion tools** | chisels, rivet setting tools, and chasing tools | decorative stamps |
| **compression tools** | anvils, swages, drawplates | Large anvils, swages, mandrels, burnishers, and rollers |
| **holding tools** | tongs, pliers tweezers, vices | Pliers, tools including substances for adhering such as a shellac covered stick |
| **cutting tools** | shears, saws, blades, punches | Shears, saws, rocking blades, hollow dies |
| **metal removal tools** | drills, gravers, scribes | Tools and materials used for abrasion, such as sand and whetstones |

**Table 7.1 Examples of tools organised by those which are found, and have not been found in British Bronze Age contexts**

Other tools might not be identified as a tool or material for metalworking. An example is the use of iron oxide as a primary ingredient for the manufacture of jeweller's rouge. In another case, a square shaped piece of ironstone excavated by the author from a Roman context in Northumbria was interpreted as a tool used for burnishing or polishing metal (**Fig. 7.1**). While this and broken pieces of pottery rich in iron oxides that have been interpreted as rubbers for polishing metal were excavated from later sites, they provide rare examples of materials needed to polish bronze that have not been recognised from earlier contexts.


**Figure 7.1 Ironstone burnishing tool. Tyne and Wear Archives and Museums**

Based on finished objects found in Britain or in comparison to tools from the continent, we would expect to see a variety of stamps and repoussé tools and a wider variety of hammers, in addition to other tools.

An example of a tool missing from the British archaeological record by inference is the snarling iron. Complex Early Bronze Age objects such as the Rillaton cup required specialised tools and sophisticated metalworking techniques. The cup would have been made using a combination of tools: a hammer, a snarling iron to form the rounded convex rings, and chasing or burnishing tools to push the metal back inwards to further delineate the rings (Untracht, 1968, 110, 252, La Niece, 2006 in Needham et al, 38) (**Fig. 7.2**). A snarling iron is used because the cups are too narrow to hammer the raised design from the inside. The snarling iron is secured in a solid base; in the illustration below a tree stump is depicted. The iron is then struck, causing it to bounce inside the cup, pushing the metal outwards. The design can then be further defined by burnishing the ridges from the outside. No snarling irons have been identified in Bronze Age Britain; however, they are necessary for the manufacture of ribbed cups (La Niece, 2006 in Needham et al, 38). This is an example of inferring the presence of tools by examining the technology and practical knowledge of the procedures for manufacturing metal objects. Using this knowledge of metalworking techniques, we can begin to fill some of the gaps in the toolkit.

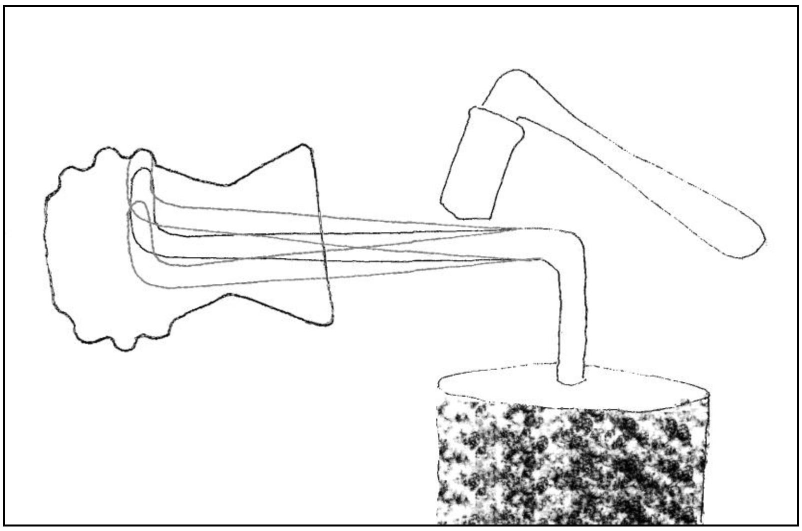


**Figure 7.2 Using a snarling iron: In order to create the ribbed design of objects such as the Rillaton and Ringlemere gold cups. Note that the term "snarling iron" is a modern term and the tool could have been made from bronze.**

## MINIMUM TOOLS REQUIRED: A SYSTEM FOR RECREATING THE METALWORKING TOOLKIT

The example of the snarling iron described above illustrates a significant question regarding the range of tools needed to produce the diverse objects found in Bronze Age contexts. By recognising the techniques and tools necessary for manufacturing metal objects, it becomes apparent that a system for organising a toolkit is needed that will acknowledge the missing tools and the various processes necessary for the manufacture of metal objects.

This section introduces a system called Minimum Tools Required (MTR), whereby the tools missing from a Bronze Age metalworking assemblage can be inferred from metal objects or from tools that are present. It is based on the idea that the presence of an object implies the existence of the tools and materials necessary for its manufacture, and that the presence of tools implies a purpose, specific tasks, and the possibility of other tools and materials that are associated with the task.

Knowledge of the metalsmithing tools, materials, and metalsmithing practice are necessary in order to know how a metal object was made. If the list of known metalsmithing tools above is consulted, a systematic approach can be used to identify any tools missing from the processes. Once all the needed tools have been recognised, knowledge of the various procedures in metalsmithing can be used to provide a means for placing the tools into the sequence of the metalworking process. By systematically mapping the procedure and noting what is needed for each step, the metalsmithing process can be made whole.

The manufacture of Late Bronze Age sheet-metal cauldrons is an example of this process (**Fig. 7.3**). The existence of the cauldrons in the Late Bronze Age suggests specific materials, tools, supplies, and techniques. Because cauldrons consist of both cast and forged sheet-metal components, in addition to being assembled by riveting, they provide an excellent example of the wide range of techniques, tools and materials that were needed to accomplish the various steps necessary for their creation. The steps in manufacturing cauldrons can be broken down into the individual tasks. For example, cast elements such as staples (lugs) and rings require a suite of tools and materials that would include tongs and bellows. Casting also requires knowledge of ceramic technology in order to manufacture crucibles, moulds, and the furnace. While there is no definitive evidence that Bronze Age smiths made their own crucibles and moulds, they would need to know and describe the proper clay bodies necessary for the different layers of moulds or for manufacturing.

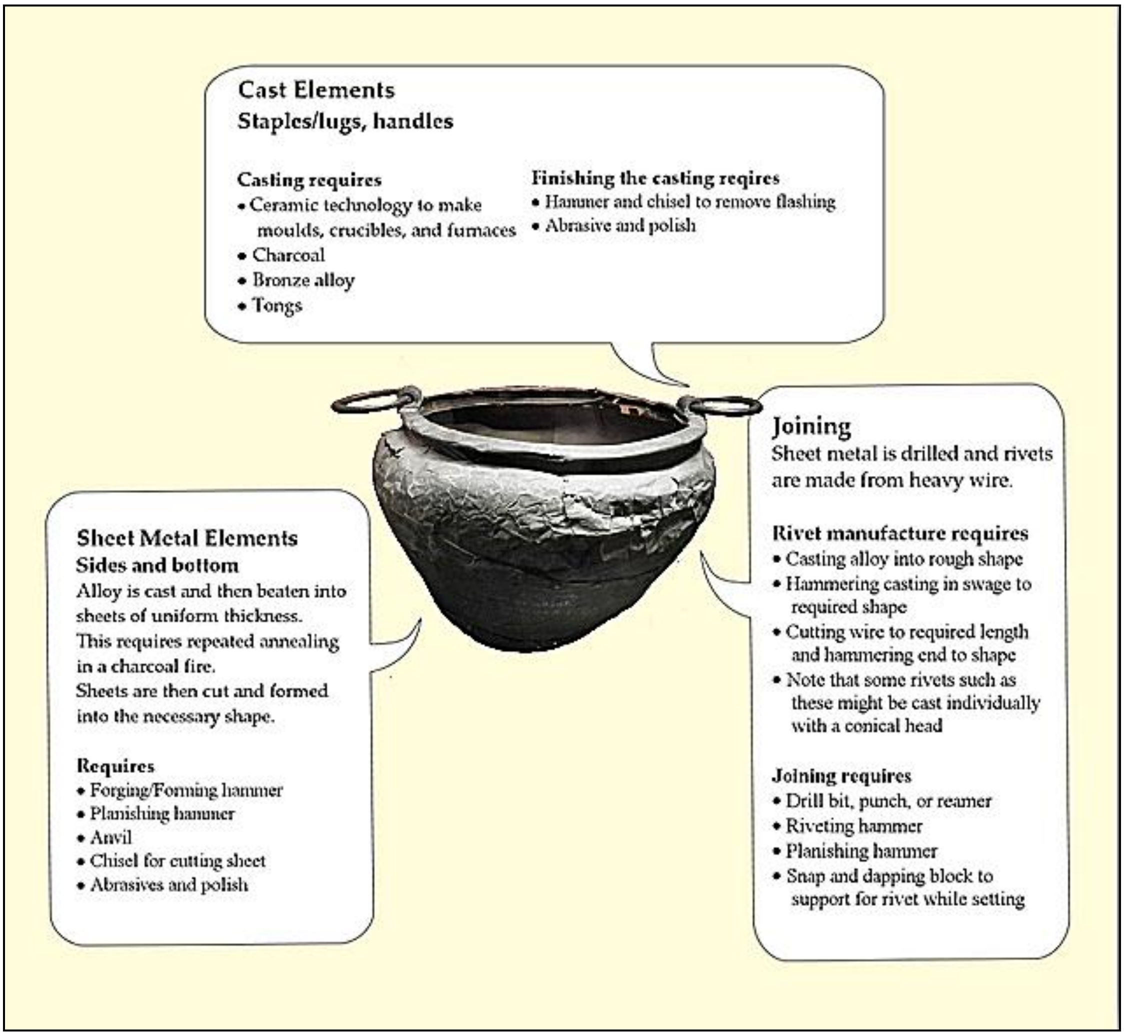



**Figure 7.3 Tools and materials needed for cauldron manufacture. Cauldron photo courtesy of Ashmolean Museum, University of Oxford.**

Once cast, the metal components must be cleaned up using a hammer and chisel to remove flashing, followed by sanding using a stone, or loose abrasives and polishes that would also require wool, leather, or cloth pads for their application.

In order to manufacture the body of a cauldron, sheet metal is first cast as thin as possible using an unleaded tin bronze and then forged into sheets of an even thickness of a few millimetres. For this task Type 2 or Type 5 hammers are needed along with an anvil that provides a firm, flat surface of appropriate size. The anvil could be made of stone or made of metal. After forging, the metal retains a ridged surface and so must be planished, or hammered smooth using a Type 1 or Type 3 hammer. Once the sheet metal pieces are completely smoothed, it must be cut into sections using a hammer and a chisel, as described in Chapter 6. If uniformity is needed, the smith might use a simple compass made from a cord and peg, or make patterns of leather so that sheet metal can be cut to a consistent size.

In addition the rounded bottom must be formed. This requires the same hammers that were used for creating the sheet metal, and it also calls for a rounded stake, swage, or sandbag in order to form the bowl shape. In addition to these, rounded mallets or bossing hammers could be used to smooth the concave surface.

Holes are then drilled or punched into the sheets for the rivets. A bronze drill bit such as the one found at Runneymede (**Fig. 4.2**) could have been used; although stone drill bits would be equally as useful. Alternatively, the holes could be punched using a Type 1 hammer and a die, along with a punch similar to the tool found in the collection in the Wiltshire Heritage Museum in Devizes (**Fig. 4.6**).

In the final manufacturing step, the cauldron is riveted together. Rivet wire can be manufactured the same way as wire, by twisting and drawing through a plate, although the rivets examined from the Iselham Hoard and those seen on riveted cauldrons in the British Museum appear to have been cast. Casting also allows rivets to have decorative heads that are either domed or spiked. The pieces of the cauldron are joined by fitting the rivet head into a dapping block or a snap, and then inserting the shank of the rivet through the holes in the metal. The rivet is then set by placing a metal tube over the protruding rivet and giving it a sharp blow. This compresses the layers of material to be joined in order to create a tight fit. The setting tool is removed and then the rivet is hammered with a Type 1a hammer so that the portion of the rivet protruding from the metal is flattened into a disk that both securely holds the pieces together and covers the hole. If the cauldron is decorated, another set of chisels would be used with a Type 1 hammer to chase the front surface, or push repoussé raised designs from the back surface of the sheet metal.

Table 7.2 illustrates the tools and materials needed for the various steps in manufacturing a cauldron, and highlights those tools and materials that have been found in British Bronze Age contexts, and those that are missing.

| Process | Tools and materials needed | Tools and materials found in the Bronze Age in Britain | Tools and materials *not* found in Bronze Age Britain |
|---|---|---|---|
| **Casting (including annealing)** | abrasives<br>bellows<br>charcoal<br>crucibles<br>furnace<br>leather gloves<br>metal alloy<br>moulds<br>tongs | charcoal<br>metal alloy crucibles<br>moulds<br>tongs | abrasives<br>bellows<br>leather gloves |
| **Sheet metal** | anvils<br>hammers<br>tongs<br>wooden mallets<br>furnace | hammers<br>tongs | large anvils<br>wooden mallets |
| **Riveting** | drill or punch<br>riveting hammer,<br>rivet set<br>rivets<br>snap or dapping block | drill<br>punch<br>riveting hammer<br>snap (possibly)<br>rivets | dapping block<br>rivet set |
| **Decoration** | chisels<br>hammers<br>pitch bowl, or other support | chisels<br>hammers | pitch bowl, or other support |
| **Cleaning and polishing (including removal of flashing)** | chisels<br>hammers<br>abrasives<br>oxide polishes<br>Leather or other pads for applying abrasives | chisels<br>hammers | abrasives<br>oxide polishes<br>Leather or other pads for applying abrasives |

**Table 7.2 Tools and materials necessary for making a cauldron**

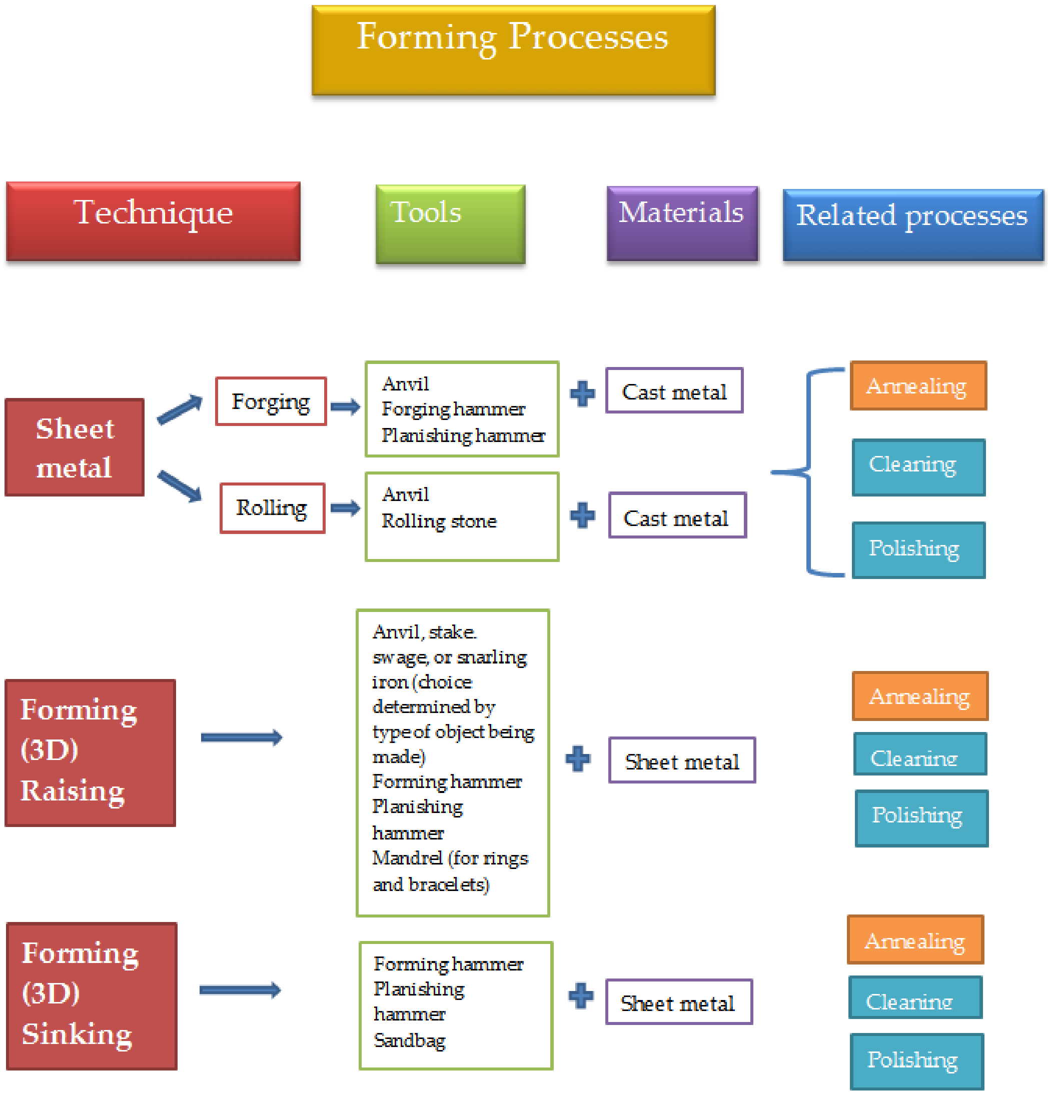
The absence of some tools can be explained by their deterioration in the burial environment, or that they were not considered appropriate to include in hoards. Some tools might also have been discovered, but not recognised for what they were.

Cauldrons are complex objects and they require an extensive range of tools. Other objects require fewer tools and processes. Ornaments similar to the gold bracelets of the Heights of Brae hoard could have been manufactured with a much smaller set of tools, such as the Type 1a hammer and anvil found in the Inshoch Wood hoard (both of these hoards are in the Inverness Museum). Because there is a wide variety of metal objects in the Bronze Age and all require various manufacturing techniques, rather than examining individual metalworking tasks, the proposed system organises the tools and materials by technique in order to provide a systematic representation of metalsmithing.

### *APPLYING THE SYSTEM*

The recognition of all the tools and processes involved in manufacturing metal objects creates connections between the tools and the finished objects found in Bronze Age contexts. Using the proposed MTR system we have a basic structure that enables the virtual, if not actual, recreation of a complete metalsmithing toolkit. Compiling a full list of metalworking tools was the first step in organising the system. This was then compared to known Bronze Age metalworking tools and materials. These were then cross-referenced and matched to categories of metalworking techniques based upon those that would be needed to make metal objects found in the Bronze Age. Because this is a system describing the *minimum* tools required it assumes the fewest possible tools necessary to complete an object, although Bronze Age metalsmiths may have had a more extensive collection of tools. A detailed schematic of Bronze Age metalworking processes is provided in Appendix 5, and brief examples of it are presented here (**Figs. 7.4** and **7.5**).

The various metalworking processes are divided into four major categories: **Forming, Decoration**, **Finishing**, and **Pyrotechnic**. Each of these are subdivided into four categories: *Techniques*, *Tools*, *Materials*, and *Related processes*. The techniques are found down the right side of the diagram (in red boxes). Moving to the left, are sub-techniques, tools, and materials. Related processes that are required to complete the task are located in the final column. Returning to the cauldron as an example, forging sheet metal requires an anvil, forging and planishing hammers (**Fig. 7.4**). The materials column indicates that cast metal is needed. Finally, the related processes include cutting (also found in the Forming Techniques section), annealing (the orange box indicates that the processes will be found in the Pyrotechnic Processes section), cleaning and polishing (the blue boxes indicating those techniques will be found in the




Finishing Processes section).

**Figure 7.4 Minimum Tools Required: Forming Processes (From Appendix 4)**

The Finishing Processes section (**Fig. 7.5**), outlines the techniques for cleaning and polishing. Tools and materials include whetstones, and leather, wool, or cloth pads that are used with sand, other loose abrasives, or metal oxides. To complete the cauldron, the Pyrotechnic Processes section would be consulted for the cast elements, and then refer to Joining techniques in order to find the tools and materials needed for riveting. Appendix 5 contains the complete system for metalworking techniques.

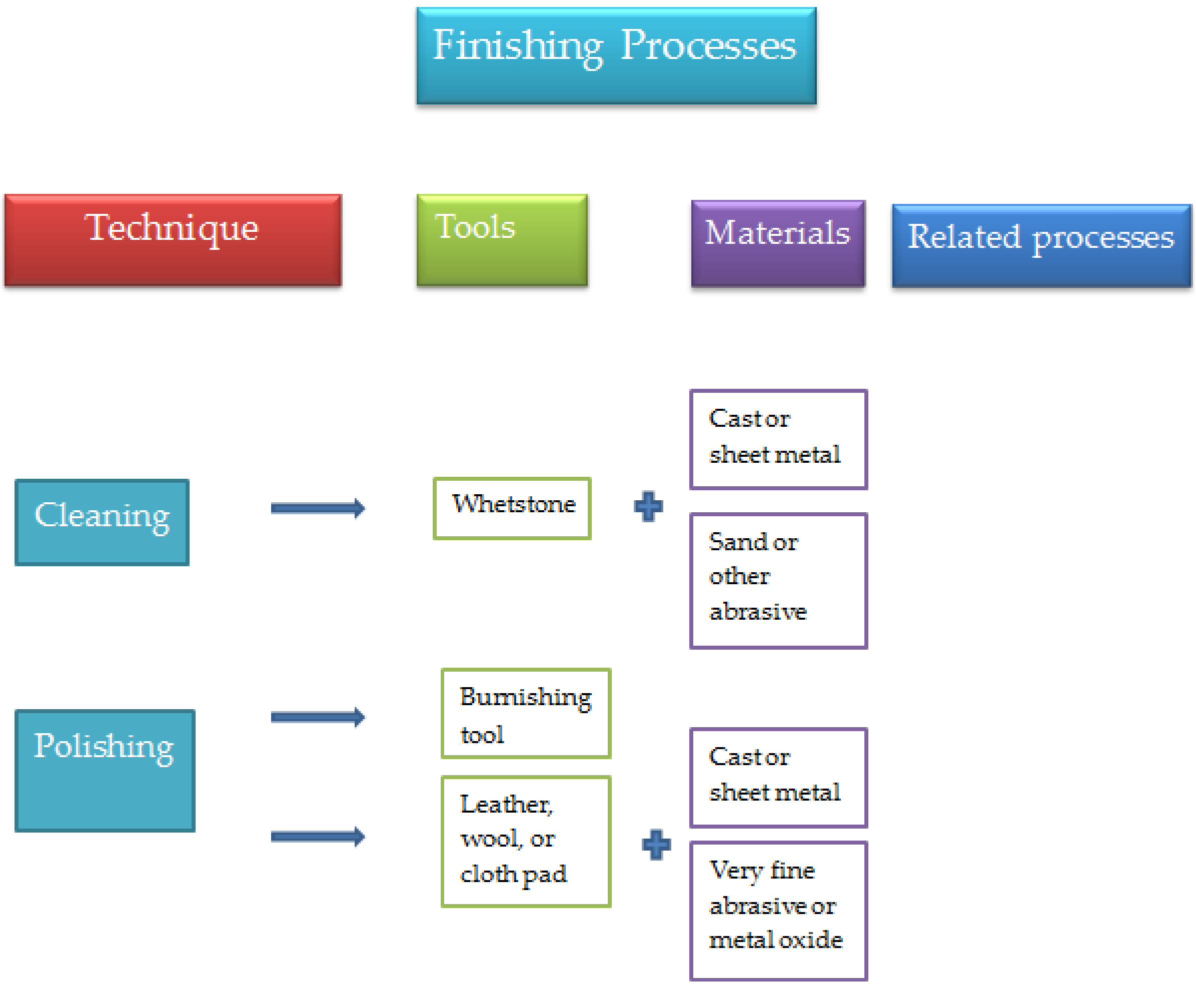



**Figure 7.5 Minimum Tools Required: Finishing Processes (From Appendix 4)**

Having a system such as the MTR not only provides a more complete vision of the range of Bronze Age tools used by smiths, but also highlights the processes of manufacturing metal objects. In addition, it can aid in alerting the archaeologist in the field as to what other materials may be found in metalworking contexts, or as an aid for the identification of metalsmithing tools in museum collections.

This system can also be used to gain insight into interpreting hoards. Since hoards are the main source we have for assemblages of metalworking tools, it is important that they be examined more closely for the types of tools they contain. By looking at tools and their relationship to other tools and objects in the hoard, they could be interpreted as an assemblage representing metalworking as a craft or indicate specific tasks. The following examples illustrate how using this system to recognise tool function and metalsmithing practice can aid in the inerpretation of assemblages.

The the Lusmagh Hoard, from County Offaly in Ireland, while not from Britain, provides a clear example of how elements of a hoard can be used to interpret the asemblage. The hoard contains an anvil and two Type 4 hammers (**Figs 4.14 and 4.15**). The anvil has a peaked working surface and two sets of two holes drilled through the spike and the flat beak. These holes could be used to either draw, harden, or straighten wire. One of the two hammers included in the hoard has a narrow, rectangular bevelled face and the other has a rounded bevelled face. The peaked surface of the anvil resembles modern stakes used for making rolled rims on the edges of sheet metal objects. Thus the anvil, with its peaked working surface and holes for drawing wire, could be used for making rolled edges that are reinforced with wire, such as those seen on gold armlets (Hook and Meeks, 2000, 29). The hammer with the long, narrow, slanted face would be ideal for turning the rim on the anvil, while the other hammer, with its wider, bevelled face would function for flattening small pieces of metal, or applying embossed decoration, as seen in the Melfort Type armlet (Hook and Meeks, 2000, 32 Figure 21B). With this knowledge, the assemblage could be interpreted as a set of tools used for making rolled edges on fine ornamental objects that were reinforced with wire. While the Melfort type armlets are dated from the Early Bronze Age and the tools from the Lusmagh Hoard are from the Late Bronze Age, the example illustrates that tools similar to the ones found in the Lusmagh Hoard were necessary for manufacturing this type of armlet in the Early Bronze Age, and also that the presence of the tools indicate that similar metalworking practices could have continued into the Late Bronze Age.

Other hoards give indications of specific metalworking practices. The Type 1a hammer and beaked anvil of the Inshoch Wood hoard (Inverness) would indicate the manufacture of ornaments or other fine metalwork. Tools such as these are necessary for the manufacture of the gold bracelets found in the Heights of Brae hoard. These bracelets could have been forged from a bar of gold and the beak or horn of a small anvil would have been used to create the flared cones on the terminals of the bracelets.

In another example, the Type 1a hammer found in the Taunton Workhouse Hoard would have been instrumental in forming the flanged torcs found in the hoard. The fine edge of the hammer would have been used to create a groove along the flat sides of a square metal bar. This not only compresses the centre of the bar, but also causes the edges to flare out slightly. This deformation gives the torcs their distinctive shape when the bar is twisted.

The Roseberry Topping Hoard provides an assemblage of tools and materials for making and maintaining agricultural tools. The hoard contained a hammer, ingot, sheet metal, and a bronze mould for casting a socketed axe. The hoard also includes two gouges, along with axes and sickle. The metalworking and woodworking tools (the gouges) would be used to manufacture the axe and sickle, including carving the handles. The hammer would also have been used to maintain the edges on the axes and sickles.

The above examples illustrate how understanding metalsmithing techniques and the systematic understanding of metalworking transform the interpretation of these hoards from being broadly associated with metalworking to one in which the hoards can be indicators of specific metalworking practices, linking the tools to the manufacture of specific types of objects.

## METALSMITHING TOOLS IN CONTEXT

In Chapter 5 it was seen that the majority of metalsmithing tools came from hoards that contain metalworking tools or materials, but as illustrated above, the generic description can be further refined to identify specific metalworking practices. By understanding how tools were used and examining them systematically, a craft-centred approach can be employed to interpret these hoards. The tools then provide more information that connects metalworking practice with the other elements of the hoard and the relationships between these objects provide a further basis for interpretation. Thus the elements of hoards that contain metalsmithing tools can be identified as parts of a specific set of tools along with the products of metalworking activities which can be used to interpret the assemblage. In essence by understanding how metal objects are made and using a systematic approach to identifying tools and materials, these hoards can be interpreted as a narrative of a specific metalworking practices.

Earlier interpretations of the objects in founders' hoards were that they were scrap for recycling (Childe, 1930, Burgess, 1974). However, rather than make assumptions about the role of the various objects that constitute hoards that contain metalsmithing tools, an examination was made of the condition of the objects in the hoards.

## Condition of objects found in hoards

Of the hoards examined 45 axes were whole, and 254 were broken or fragmented. A sword from the Minnis Bay Hoard was the only one found whole; all other swords included in hoards that also contained metalsmithing tools were fragmented. Gouges and chisels were also found whole, fragmented, or damaged. In addition, only two whole ingots were found, in contrast to over 600 fragments of ingots. Various fragments of cauldrons and buckets were also found that included both cast elements, small pieces of sheet metal, and rivets. Interestingly, bronze moulds have always been found whole, and often with both valves present.

The traditional interpretation for the presence of the fragmented objects in these hoards was that it was scrap destined for recycling  (Evans, 1881, Childe, 1930, Burgess and Coombs, 1979). Burgess and Coombs (1979) wrote that the reason for fragmentation was that the metal was reduced to pieces that could easily fit into a crucible. Turner (1998a) also noted this, but she could not account for the inclusion of larger pieces and objects that were interred intact (Turner, 1998a, 88, 102, 111). Turner also questioned why there were so few cauldron fragments, and why so little of a cauldron was included if hoards were composed of objects that were reduced in size for recycling  (Turner, 1998a, 106).

In her examination of the types of fragmentation Turner noted that in the large hoards found in Essex and Kent, the fragments of axes could not be reassembled. There were many fragments of axes, but they were from different individual axes. This is remarkable considering that some of the hoards, such as the Vange Hoard from south Essex contains 116 fragmented axes, swords, and knives. Turner concluded that the patterns of fragmentation and destruction were inconsistent, and did not appear to be for the purpose of making them easier to recycle. Rather, these fragments were deliberately chosen by the smith for symbolic reasons (Turner, 1998a, 89, 116).

More recent work by Bradley (1985a, 1998), Chapman (2000), Brück (2008a) and Dolfini (2011) suggest alternative interpretations that focus on the symbolic meaning of fragmentation of objects. The fragmentation of objects changes their meaning

(Bradley, 1985a). The tool is redefined, and instead of functioning as a tool, its meaning had been renegotiated to be fit for its new context (Dolfini, 2011). These assemblages could symbolise fertility, death, and regeneration (Brück, 2006b), or represent the social cohesiveness of a community (Chapman, 2000).

Despite the fragmentary condition of the majority of objects in these hoards, metalworking tools are most often found in workable condition. Turner noted that hoards found in the southeast of England tended to have intact tools, including hammers, chisels, gouges, and knives (Turner 1998, 111). In the data presented in Chapter 5 in those hoards in which multiple hammers were found, at least one hammer was intact, and of the 71 hammers examined, only three were damaged to the extent that they could no longer be used. However, this damage does not resemble the damage sustained by other objects found in hoards. Hammers are not broken into pieces, or have sockets smashed flat or jammed with other objects.

Hammers and some chisels exhibit evidence of use, such as burring or small dents, others have evidence of maintenance in the form of fine parallel scratches as quantified in the schematic in Chapter 5. Of the hammers that were not too corroded, all of them had evidence of wear either in the form of burring, abrasion, or small dents as described above. In addition there was no flashing evident on the face, although flashing was often present on the sides of the heads. The implications are that these hammers were deposited in a used, but still useful state.

The examination of artefact condition is useful in that it demonstrates that metalworking tools were treated differently than other objects found in hoards. Unlike the fragmented swords and axes included in these hoards, the tools of the smiths appear to be still useful, indicating that metalsmithing tools had a different significance than other objects in the hoard. Their condition sets them apart from other elements of the hoards and raises questions as to why they were included. It was shown in the experiments in Chapter 6 that hammers and chisels could be used to break metal objects with minimal damage to the tools and that there were no other tools with which to destroy the hammers. However the question then arises as to why a useful hammer would be buried with the broken objects that make up the hoard. Since these tools would have been used to fragment the other objects found in these hoards, it appears that they were afforded special status.

### Experimental work and insights into tool function

Before interpretations can be made about the condition of tools and their use, the wear needed to be examined and quantified. In order to do this, replica tools were made for the series of experiments in Chapter 6 and were used to perform tasks so that they could be compared to the original artefacts examined in museum collections.

Using replica tools gave a good approximation of how the original tools could have been used and provided information about their durability and limitations. Using data gathered from original artefacts and replicas based on their analyses, the use wear on hammers revealed information about the way in which smiths used their tools: it was noted that the wear on the hammer faces used in experiments was uneven and that this could be associated with handedness. Experimental work showed that when a right-handed person used the hammer, the wear on the apex of the hammer face occurred on the proper left of the face, and that the reverse was true when a hammer was used by a left-handed person. Of the 24 Type 1 hammers examined in museum collections and described in Chapter 5, two examples had a distinct apex that ran straight across the face and matched up with the casting seams. A total of five had evidence of wear that pushed the apex toward the top, indicating more wear on the proper left side of the face (**Fig. 7.6**). No hammers exhibited this wear to the proper right. The remainder of the hammers were either too corroded, or the face had been abraded so that the apex could have been restored to its original position. The proper left damage indicates that Bronze Age smiths who used these hammers were likely to have used the tools with the right hand. A complete list of the condition of hammers, including asymmetrical wear on the faces can be found in Appendix 3 and photographs of all the tools examined can be found in Appendix 1 on the attached CD-ROM .

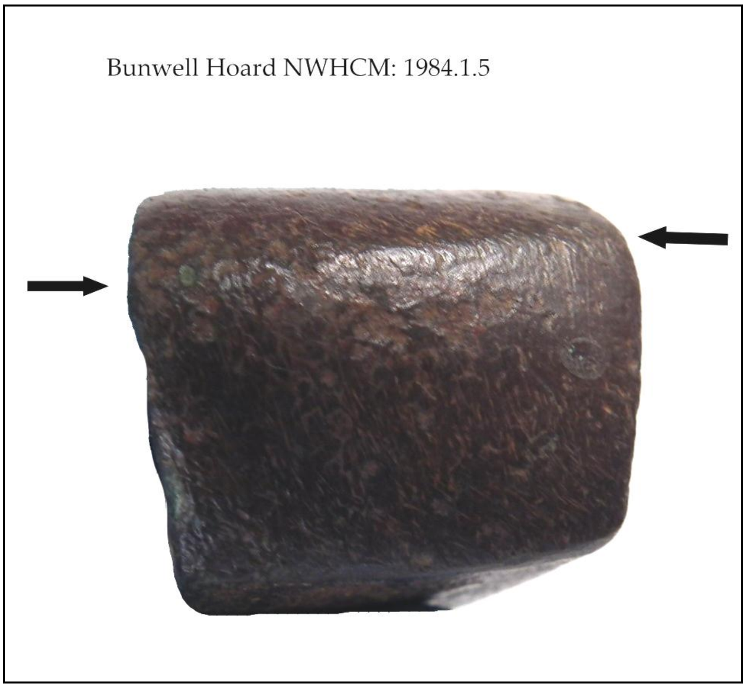



**Figure 7.6 Type 1 hammer with distorted apex: Note that the apex is higher on the PL of the face. Apex is 10.5 mm from top edge on PR and 7 mm on PL. (Norfolk Museums & Archaeology Service)**

## Contents of hoards

Although tools are the defining element of the hoards selected for this study, the other objects in the hoard are often so numerous that they overwhelm the small set of tools that are included. While the Grays Thurrock Hoard has three hammers, an unusually large number for a hoard, the entire hoard consist of 298 objects that include fragments of socketed axes and Ewert Park swords. A similar situation is seen in other hoards in southeast Britain, where hoards tend to be larger. However other hoards such as the Northampton hoard which includes 24 axes, axe fragments, fragments of swords, spears, and knives has only one hammer and one chisel.

A list of the objects that constitute the hoards examined for this study is found in Chapter 5 (**Table 5.1**). Of the 32 hoards examined, having one hammer is common, and hoards with more than one hammer are much rarer (**Fig 5.8**). The inclusion of other metalworking tools such as anvils, tongs, hones, or vices is exceptional. These types of tools are often known only from individual examples, such as the tongs from the Heathery Burn Hoard.

The hoards containing metalsmithing tools also contain other types of objects that are not metalworking tools but are produced by metalsmiths. In order to interpret these hoards we can interrogate these objects as to how they relate to the tools that are represented in these hoards.

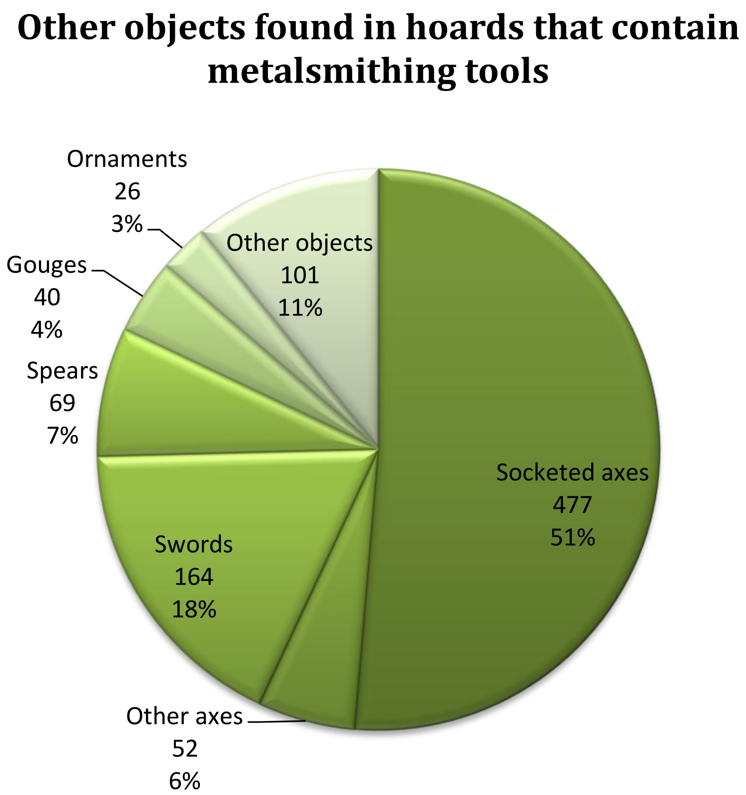



**Figure 7.7 Other objects included in hoards that contain metalsmithing tools based on 30 of the hoards examined, all of which contained metalsmithing tools, in addition to six other hoards that were unavailable, but have been published. These hoards have a combined total of 1556 elements including a total of 627 ingots. The ingots will be discussed in more detail below. Note that the Isleham and Salisbury hoards are not included in this data. Total numbers are given above percentages.**

Figure 7.7 shows finished objects included in hoards that are not metalsmithing tools. Of the hoards included in the study, the most common objects included were socketed axes. Weapons (swords and associated equipment such as chapes) and spears make up the second largest category, although it should be noted that spears could be interpreted as tools for hunting rather than weapons. Of the smaller categories, gouges and other types of axes also make up a notable percentage. Ornaments are rare, as are agricultural tools such as adzes, sickles, and other objects such as bugle-shaped objects that are included in the "Other" category.

The example of the Roseberry Topping Hoard presented earlier demonstrated how the non-metalworking components of these hoards can contribute to a fuller interpretation of the entire assemblage. Rather than being scrap, the total elements of the hoard associate metalworking with other activities practiced in the Bronze Age. Examples such as the Roseberry Topping Hoard connect metalsmithing with agriculture, and the Taunton Workhouse Hoard connects smithing with prestige objects in the form of ornaments. Recognising all the elements that make up hoards that include metalsmithing tools enable us to see patterns that indicate metalworking practices, but also suggest other activities, such as agriculture (sickles), defence or martial aggression (swords, other weapons, or associated items such as chapes), or prestige (ornaments). In the following section an examination of the contents of hoards will be used to provide interpretation of specific metalsmithing activities.

## Interpreting hoards based on content

The hoards used in this study are defined by the presence of metalworking tools; however, until now little discussion has been made as to the types of tools included and their function, other than their general association with metal as a craft. As seen earlier, the types of tools and objects found in hoards indicate specific tasks that can be interpreted by using knowledge of metalsmithing practices. By understanding activities associated with metalsmithing and using the Minimum Tools Required system, a more detailed interpretation of hoards can be made. Table 7.3 and Figure 7.8 provide a very brief interpretation of the hoards examined for this thesis based upon both metalsmithing tools and non-metalsmithing objects.

| Hoard | Metalworking tools and materials | Other objects | Possible metalworking activities |
|---|---|---|---|
| **Bunwell Hoard** | Scrap bronze, type 1 hammer, socketed gouge | Axes, fragments, knife, ring | Casting, hafting, sharpening, fragmentation |
| **Burgess Meadow Hoard** | Type 1a hammer, tanged chisel, | Palstave, spearheads, hammered rod | Forging, riveting, casting, hafting, sharpening |
| **Carleton Rode Hoard** | Gouges, chisels, type 1a hammer, and ingots | Palstave, axes, spearhead fragment | Hafting, riveting, casting, fragmenting |
| **Cranwich Hoard** | Type 1 hammer, ingot | Axes, fragments, knife fragment | Casting, sharpening, fragmenting |
| **Donhead St. Mary's Hoard** | Bronze mould, type 2 hammer, socketed gouge | Lump of bronze, bundle of wire, whetstone, axes | Forging, sheet metal, casting, hafting, and sharpening |

| Hoard | Metalworking tools and materials | Other objects | Possible metalworking activities |
|---|---|---|---|
| **Grays Thurrock Hoard** | Type 1 hammer, type 3 hammer, chisels, gouge | Casting debris, ornament, cauldron, ingot, | Casting, sheet metal work, riveting |
| **Hatfield Broad Oak Hoard** | Type 1 hammer, ingots | Bucket, spearhead, socketed axe, bugle object | Sheet metal, casting, sharpening, fragmenting |
| **Hevingham Hoard** | Type 1 hammer, bronze mould for socketed axe | Axe, fragments, | Casting, fragmenting, sharpening |
| **Isleham Hoard** | Bronze mould, type 1 and 1a hammers, draw plates, rivets | Over 6500 objects, including axes, sheet metal, weapons | Wire making, riveting, sheet metal, forming, sharpening, fragmentation |
| **Inschoch Wood Hoard** | Type 1a socketed hammer, anvil | Spearhead, | Ornaments |
| **Isle Of Harty Hoard** | Type 1 socketed hammers, whetstone, ingots, possible snarling irons, bronze moulds | Axes, ornaments, knives | Casting, hafting, sharpening, forging, |
| **Kilnhurst Hoard** | Type 1 and 5 hammers, chisel | Spear, axes | Forging, sharpening |
| **Kirkton Hoard** | Type 1 hammer | Knife, axes, gouge | Sharpening, hafting, woodworking |
| **Leigh Ii Hoard** | Sheet-metal, type 1a and 5 hammers, metalworking debris, ingots | Axes, knives, weapons, cauldron, fragments, | Forging, forming, riveting, casting, fragmenting |
| **Lusmagh Hoard** | Type 4 hammer, anvil, graver, trunnion chisel, gouge, punch, possible rivet snap, polishing stone | Socketed object | Ornaments, riveting, sharpening, wire making |
| **Minnis Bay Hoard** | Type 1 hammer, scrap metal, ingot | Axes, cauldron fragments, ornaments, weapon | Casting, sheet metal, sharpening |
| **Minster Hoard** | Type 1ahammer, metalwork debris, ingot | Axes, weapon, decorative work | Casting, ornaments, riveting |
| **Northampton Hoard** | Casting jet, ingot, type 1 hammer, mortising chisel, | Axes, knives, swords, spearheads, bucket baseplate, vessel fragments. | Sheet metal, sharpening, casting |
| **Reach Fen** | Gouges, type 1a hammer, chisels, casting scrap | Axes, swords, fragments, spears, buttons, bugle objects | Casting, hafting, sharpening, riveting, ornaments |
| **Roseberry Topping Hoard** | Type 3 hammer, bronze mould, gouges, and chisel, sheet metal, whetstone, ingots | Sickle, socketed axes, jet | Casting, hafting, sharpening, sheet metal |

| Hoard | Metalworking tools and materials | Other objects | Possible metalworking activities |
|---|---|---|---|
| **Salisbury Hoard** | Over 535 objects, including types 1, 1a, 3, 4, and 5 hammers, chisels, gouges, punches, anvil, | Sickles, axes, daggers, knives, chapes, ornaments, toilet articles, miniature shields, and miniature cauldrons | Forging, forming, sheet metal, ornaments, riveting |
| **Swalecliffe Hoard** | Hammers (?), gouge, chisel, ingot fragment | Axes, adze, sword, knife, chape | Casting, hafting, possibly sharpening |
| **Taunton Workhouse Hoard** | Type 1a hammer, | Ornaments, axes, spears, sickle | Ornaments |
| **Thorndon Hoard** | Awl, gouge, type 1 hammer, | Axe, knife, spear, cremation urn | Sharpening, hafting, possibly setting rivets |
| **Vange Hoard** | Type 1 hammer, ingot | Axe, fragments | Casting, sharpening, fragmentation |
| **West Kennet Hoard** | Gouge, type 1 hammer, chisel/graver | | Sheet metal, forming, hafting |

**Table 7.3 Interpreting hoards based on contents. Detailed lists of hoards, their components, current locations, and references can be found in Appendix 4.**

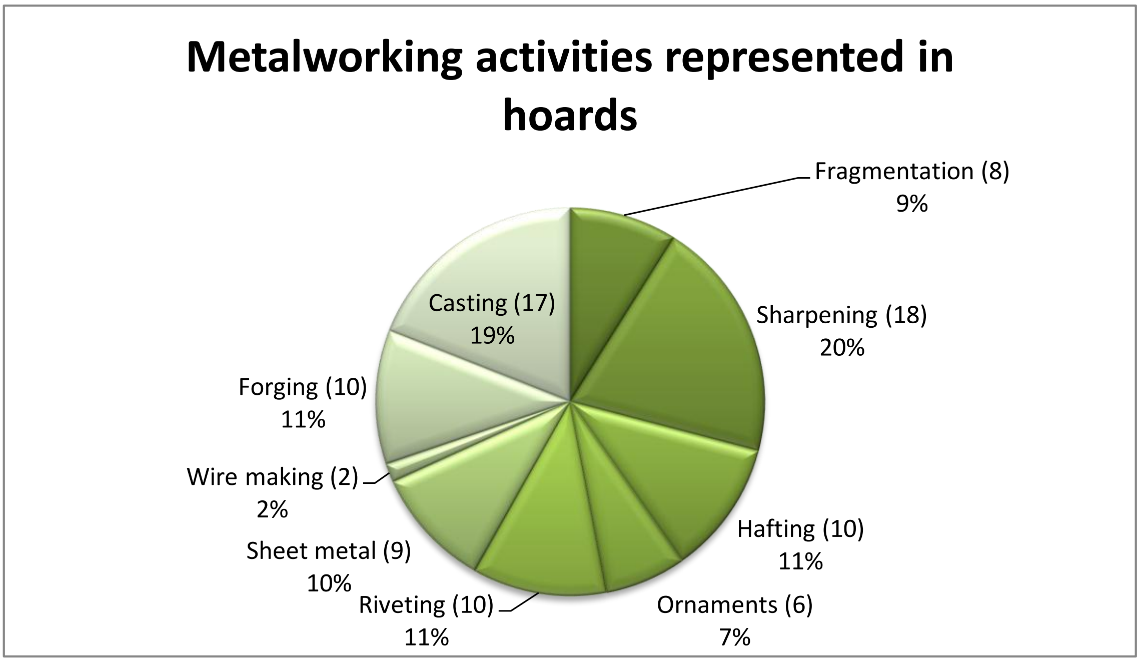



**Figure 7.8 Metalworking activities represented in hoards. Total numbers are given in parentheses.**

The chart above can be interpreted as representing the lifecycle of metal objects that begins with tasks such as casting, forging, making wire and sheet metal, riveting, making ornaments, sharpening, and hafting. Sharpening and hafting can also represent the use-life of an object since these are necessary for maintenance throughout the life of an object such as an axe, sickle, or sword. The end of the object's life is represented by fragmentation. It is interesting to note that while fragmented objects make up a large percentage of many hoards, in the number of hoards represented here, fragmentation is not as popular as the creation of objects.

Table 7.3 and Figure 7.8 show how interpretation can be aided by understanding how tools are made and used for metalworking tasks. Using a systematic approach, such as the Minimum Tools Required presented in this thesis provides the means for better interpreting hoards. By identifying the tools and knowing their function and place in the craft of metalsmithing, a more precise assessment of the type of metalworking activity can be made, and a hoard could be interpreted as part of a set of tools used for making gold bracelets with flared terminals. Thus by understanding the functions of tools found in assemblages, the interpretation of the hoard shifts from that of general metalworking to a metalworking assemblage that highlights the manufacture of fine ornaments.

The anvil of the Inshoch wood hoard has no holes or grooves, but others, such as the one found in Sutherland that has several grooves, and could have been used to make wire. The forms of the different anvils provide additional clues as to the types of metalworking that was practiced. Anvils with peaked tops can be used for rolled edges or other curved objects, such as hollow sheet metal bracelets or bracelets with rolled, reinforces edges. Grooves or holes can indicate wire making. Beaks can be used for forming flared cone shapes, rings of various sizes, or for bending wire or metal. A flat surface on an anvil can be used for hammering sheet or sharpening an axe or other bladed object.

Casting formed one of the major activities represented in metalsmithing hoards (**Fig. 7.8**). From this data it would appear that casting was emphasised as the type of metalworking paraphernalia appropriate to include in these particular hoards. While bronze moulds are relatively rare, over 600 ingots were included in the hoards examined. The number of ingots varies widely from hoards that contain a single ingot fragment to the Vange hoard (Colchester) with 142 ingot fragments. Ingots can be cast into any object desired; however, if the other metalworking objects found in the hoard are considered as a set representing specific metalworking techniques, then by using the information contained in the Minimum Tools Required charts in Appendix 5, the combined information can provide a foundation for interpretation. For example, hoards in the south and southeast including Hatfield Broad Oak, Haxey, Minnis Bay, Grays Thurrock, Northampton, and Leigh II all have ingots and fragments of cauldrons. These hoards also contain Type 1, Type 1a, or Type 2 hammers, and the presence of ingots could be further interpreted to indicate sheet metal work. The combination of the various elements could indicate the process of manufacturing cauldrons. In a specific example, the Grays Thurrock Hoard has seventy ingots that weigh slightly over 14 kg, in addition to one fragment of an ingot of leaded bronze. The sheet metal necessary to complete a Colchester type cauldron would weigh 9.3 kg with an additional 0.2 kg for rivets (estimated from information in Gerloff, 1986). If this is subtracted from the weight of the ingots in the Grays Thurrock hoard, the rings and staples could be cast from the remaining 4.5 kg of metal (that includes the leaded ingot found in the hoard). This weight would also include an allowance for the necessary casting jets. The presence in the Grays Thurrock Hoard of three hammers (one Type 1 and two Type 3 hammers) adds to the interpretation of the hoard having a focus on sheet metal manufacture. In essence, the metalworking assemblage of the Grays Thurrock Hoard could constitute the necessary tools and supplies for manufacturing a cauldron.

The Grays Thurrock Hoard also contains fragments of cauldrons. This could lead to further speculation for interpretations of creation and destruction, beginnings and endings, birth and death. As seen in Chapter 3, cauldrons have been powerful symbols in mythology and equated with feasting, healing, and regeneration. Some of the Colchester Type cauldrons are very large, capable of holding 60-70 litres and were interpreted as cooking vessels for communal feasting (Gerloff, 1986, 2010, 93). This assemblage could not only be interpreted as having the tools and materials to manufacture a cauldron, but it could also contain the remains of an event that involved feasting that was also a part of a greater cycle of creation and destruction, of which feasting was a focus. Brück used the fragmentation of cooking pots and their re-use and deposition as examples that were symbolic of transformative processes that also were reflected in metalworking technology (Brück, 2008a, 304, 307). Turner explored the reasons for fragmenting metal objects, noting that few fragments of cauldrons were found and that their deliberate inclusion indicated that their meaning “survived the fragmentation process" (Turner, 1998a, 118). She also wrote that the fragments of objects found in hoards were chosen by the smith as symbolic objects, and it would also have been the smith who had the tools and knowledge to reduce these objects to fragments (Turner, 1998a, 89, 116).

### Tools as symbols of smiths and craft: What can we infer from the presence of metalworking tools in hoards?

Chapter 2 described how the smith often had high status, and in various cultures smiths could claim to have a unique lineage different from other humans, often through a special descent from gods. They were associated with healing, shamanism, and magical abilities beyond those of the craft of metalworking. This knowledge and skill enhanced the prestige in the objects they made, and the smith's power was believed to have resided in their tools and the objects they made. Tools such as hammers have been used as symbols of smiths in art and myth, and they represented the smith's power of creation and destruction.

Drawing on the example of the hammers given to Igbo smiths at their initiations, or the hammer in depictions of Hephaestus (Chapter 2), tools such as hammers symbolise the smith or the craft of metalsmithing. Also, when considering the condition of the smith's tools in hoards, the still useful hammers and other smithing tools could have been included as a representation of the smith or the contribution of the smith's power to the hoard. When this is combined with knowledge of metalsmithing practice, the tools are elevated from a passive indicator of a hoard type and can be used to indicate specific craft practices, and can provide further interpretations of social activity. The inclusion of these tools points to the recognition of the smith as an active agent in the creation and destruction of the objects that constitute these hoards. Thus the smith is represented by the presence of tools and materials that accrued meaning and value through social interaction, communicating both identity and power (Chapter 3).

In Chapter 3 it was seen how significant objects retain essentialist qualities from their creator and those who possessed them, creating a network of relationships that is represented by the object. If those portions of fragmented objects that were not deposited in a hoard were retained, it could be that the fragments were kept as a souvenir of a communal event in which individual members were consolidated as a group. If the fragments were used to create new objects, then the new objects could retain connections to the hoard and the event surrounding its deposition.

All of these scenarios show the smith as having a prominent role in the formation of these hoards: as the creator of the objects in the hoard and as the agent of their destruction.

It is through knowing how tools are used and recognising tool function and wear we can begin to piece together the processes that went into creating hoards. By knowing how metalsmithing is practiced, and the sequence of actions necessary to accomplish making metal objects, we can translate the wear and condition of the objects into actions performed by the smith.

## *CONCLUSION: THE ASSEMBLED TOOLKIT*

The examination and analysis of the tools were used to replicate tools for a programme of experimental work. The experiments were used to identify how the tools could have functioned and to compare wear and damage to the original tools, and aided in recognising missing tools. This resulted in a system designed to recognise the toolkit needed for Bronze Age metalsmiths to accomplish metalworking tasks.

This systematic study of metalsmithing tools and their function led to a more complete understanding of the processes of Bronze Age metallurgy in Britain. By examining the types of tools and understanding their functions, we now have a better grasp of how Bronze Age metalsmithing was practiced. This systematic study enabled the identification of tools that are missing from the archaeological record. By organising tools and their uses, experimental work demonstrated how we can recognise the movements of the smiths' hands in finished objects, and even enable us to make statements as personal as handedness.

By developing a system that emphasises tool function, metalworking assemblages can now be examined and organised with an aim to recognising their components and place them in the practice of metalsmithing. The system could also be used to work in reverse by examining a finished object in order to determine the types of tools and materials that are needed for its creation.

This thesis also recognised that the majority of metalworking tools came from Late Bronze Age hoards in eastern and southern Britain, a region in which metal ores are not found. These hoards, identified by the hammers and other metalsmithing tools included in them, have barely been studied for the components that are most closely connected to smiths. This thesis used these tools not only to identify their function, but also to explore their inclusion as clues for interpreting hoards as a representation of smiths and their craft. By knowing and understanding the hoard components and their relationships, we can begin to read these hoards as a narrative of metalsmithing practices.

Together, the combined results of the different approaches presented in this thesis form a basis that will enhance the understanding of Bronze Age metalworking, and provide a foundation that will place metalsmithing tools in the context of the manufacturing process. In addition, this thesis focused on an agent-centred practice with the aim to understand how the actions of skilled practitioners are manifested in the material culture of the Bronze Age in Britain.

## FURTHER STUDY

### *METALWORKING*

**Continuing traditions in the British Iron Age** The deposition of both bronze objects and tools continued into the Iron Age (Wait, 1985). However outside of specialist metallographic work done by Fell (1993, 1995, 1998), there have been no function-based studies of hammers and other metalworking tools during this time of technological shift. A continuation of this thesis could examine the transition from bronze metalworking tools to iron, and the ways in which tools were adapted to work with the new medium.

**Bronze Age metalworking tools in Ireland and the continent**

This thesis was limited to the study of metalsmithing tools of Britain. However it was noted that both similarities and differences exist between the types of tools and the depositional practices between Britain, Ireland, and the continent. While British tools are more limited in types compared to those found on the continent, those that have been found bear resemblances to tools on the continent. However, many of the metalsmithing tools found in Ireland are unique, and the types of hammers found in Ireland do not resemble hammers found elsewhere in the Bronze Age. Further study would examine these contrasts in order to understand differences in tool development and its effect on metalsmithing practices, in addition to studying how the craft was represented in depositions.

### *HOARDS AND INTERPRETATION*

**Ingot hoards**

While examining hoards containing ingots, it was noted that some hoards (Goldhanger Hoard, Colchester Museum; Leigh II, Southend Museum) also contained an ingot with high levels of lead. Because the lead was buried with copper, it developed a green patina, although the lead oxide resulted in a more whitish green than the yellowish green of the usual copper corrosion. This was confirmed by chemical analysis undertaken with a pXRF. It would be beneficial to re-examine hoards that contain multiple ingots with an aim to using chemical analysis to see if the inclusion of lead ingots is a wider trend. Such a study would address questions such as whether the proportions of lead to copper would agree with proportions used in Late Bronze Age alloys, and if this is a local or regional practice. In addition the presence of leaded ingots has implications regarding alloying processes and sequences used by Bronze Age smiths.

## *METALS*

### Silver

In the course of this research, objects were analysed for various metals, including copper, bronze, tin, arsenic, lead, nickel, gold, and others. All of the metals found everywhere in the world during this period are represented in Britain with one rather obvious exception, that of silver. While silver ore is found in Britain in the form of galena, a lead ore that was known to have been exploited during the Bronze Age, there is no evidence of refining the ore for silver. Curiously, there are no silver objects or silver metal found in Britain until in the Iron Age and it appears there is an entire category of metals that up until now has not been studied.

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# Appendix 1: Glossary of metal terms

***Alloy*** A metal created through the combination of two or more metals. This can be a natural combination found in ores, or deliberately produced by combining refined metals.

***Annealing*** A heating process whereby the crystalline structure of a metal or alloy becomes relaxed. The result is that the metal softens and ductility is restored so that cold working (forging, forming, drawing, etc.) can resume without stressing the metal

***Anvil*** A working surface specifically for a metalworking task where metal can be supported while hammering, forging or forming. Anvils can be stone, wood (such as a hardwood tree stump), or metal. The working surface can be flat or shaped to allow a specific task (see also *Swage* and *Stake*). Anvils can also incorporate *beaks* or *horns*, conical or elongated pyramidal extensions that aid in the construction of more complex shapes. Some anvils also incorporate *Drawplates* or *Swages*. Smaller anvils might also have spikes, used to secure them into a larger work surface, such as a stump. Bronze Age anvils have been classed into three categories: *Simple, Beaked*, and *Complex* (see Chapter 5).

***Awl*** See *Graver*

***Bellows*** A means for delivering air to a furnace in order to increase the temperature. There are no remains of bellows from the Bronze Age, other than *tuyeres*. However, ethnographic and historical examples include box bellows and bag bellows, in which a chamber is filled with air (either by pulling a plunger back on the box with a valve allowing air to enter, or by opening the bag while lifting) and then the air is expressed (pushing the plunger forward causing the valve to close, or by closing the bag and pushing down) through the tuyere and into the furnace.

***Blowpipe*** a long tube that is blown in order to introduce air and increase the temperature of burning charcoal. This can be used for furnaces, where a team of people would be employed, or for increasing the heat from a piece of charcoal, such as would be done for soldering. Blowpipes can also be used to blow dross from the surface of molten metal before casting.

***Burnisher /Burnishing tool*** A stone or metal tool used to create a polished surface by forcibly smoothing it, or to push metal such as for setting stones. Burnishing can also be used to 'erase' light marks on metal surfaces.

***Burr*** A deformation of metal where it has been pulled beyond the normal edge of a tool or object causing an irregular flange.

***Casting*** A process where metal is melted and poured into a mould.

***Chasing*** A method of decorating the surface of a metal object using various chisels and punches that are struck by a hammer in order to incise a design. Chasing can also be used to score a line in sheet metal in order to create a sharp bend, or to cut the sheet.

***Chasing hammer*** A lightweight hammer with a wide face used to strike the end of a chasing tool (see *Chasing*).

***Cope and Drag (Sand casting)*** A system for creating a mould from packed sand. A flask or frame is made of wood and the bottom is filled with prepared sand (the *drag*). This is compacted by pounding and then smoothed. A model of the piece to be cast is pressed into the surface of the sand. After coating with charcoal dust or ash (parting powder), a second frame is fit over the first and filled with sand the *cope*) that is also compacted. The halves are carefully separated, the model removed. An opening (casting cup) is cut into the sand where the molten metal will be poured into the mould.

***Core*** A mould piece that is inserted into a mould in order to produce a hollow or socketed casting.

***Corrosion*** The result of a chemical reaction between metal and moisture. Corrosion can form a protective film (see *Patina*), or can be destructive causing pitting or conversion of metal to an oxide form.

***Crucible*** A ceramic vessel used to hold metal while melting, or ore when *Smelting.* Crucibles are made of a refractory material that includes clay and tempers to help it withstand high temperatures and thermal shock (See Appendix 2).

***Crystallisation*** The formation of a specific structure that occurs as metal cools after being heated.

***Dapping block*** a small block, usually of hardwood with circular depressions. Similar to a *swage*, a dapping block can be used to support a rounded rivet head, or to sink metal into a domed shape.

***Drawing*** The process of pulling wire through a drawplate to harden it or to reduce its diameter.

***Drawplate*** A heavy metal plate pierced with holes through which wire is pulled. The holes are of various sizes so that the wire can be drawn through the largest and proceed through increasingly smaller holes to make a finer wire.

***Dross*** The skin of oxidised metal that forms on the top of molten metal. This must be removed by skimming or blown off with a blowpipe before casting.

***Ductility*** The ability of metal to stretch or deform as a result of hammering, drawing, or rolling.

***Engraving*** The decoration of metal using a fine, sharp tool, such as an awl or graver, that scratches a design in the surface.

***Flashing / Flash*** Thin flanges of metal that form in the fine gap where the *valves* of the mould meet.

***Forging*** Shaping or forming metal using specialised hammers and anvil.

***Forging hammer*** a hammer designed for forging metal. The face is wedged shaped in order to direct the deformation of the metal in the desired direction.

***Forming*** The process of shaping metal from a flat sheet into a three-dimensional object. This can either be done by raising (forming over a *stake*) or *sinking (*pushing the metal into a hollowed form such as a *dapping block* or *swage*).

***Furnace*** A structure, usually lined with *refractory* material used to contain heated charcoal and *crucibles*. Furnaces can be cylindrical structures or shallow pits with openings for *tuyeres* at the surface, or below.

***Gangue*** the unwanted constituent parts of ore. This is usually removed prior to smelting by beneficiation (crushing and sorting).

***Graver*** A sharp tool used to incise designs onto a metal surface. Unlike *chasing*, the tool is guided by hand rather than using a hammer.

***Jet*** The excess metal attached to the top of a cast object. Also known as a casting cup.

***Mould*** A form with a cavity into which molten metal is poured. Moulds can be made of packed sand (see *cope and drag*), ceramic (see *refractory*), stone, or bronze. Moulds can have single or multiple *valves.*

***Native metal*** Metal that is found in a naturally pure state.

***Ore*** A composite mineral that contains metal. The ore must be *smelted* in order to extract the metal.

***Patina*** a benign form of corrosion that protects the metal surface.

***Pattern*** An object used as a model for making a mould. Patterns can be made of wood, lead, wax, or ceramic. They can also be previously cast objects, in which case moulds are made to create duplicate objects.

***Planishing*** The act of smoothing a metal object using a stake or anvil and a *planishing hammer*

***Planishing hammer*** A specialised hammer with a slightly curved perfectly smooth face.

***Punch*** A rod-shaped tool used with a hammer to create holes in metal.

***Raising*** The process of forming a three-dimensional object from sheet metal by hammering it over a stake or anvil.

***Refractory*** A ceramic material made from a paste that includes specific materials to withstand high temperatures and reduce its susceptibility to thermal shock (see Appendix 2).

***Repoussé*** A decorative process where the design is worked with hammers, punches and chisels from the reverse side of the metal. The design is often further defined by *chasing* more detail on the top surface of the metal.

***Rivet*** cast metal rods with a preformed head on one end. The head can be flat or decorative.

***Riveting*** A cold working process where metal is joined by rivets threaded through drilled or punched holes. The head is supported on a *dapping* block or *snap* and then the reverse is hammered so a head is spread, extending beyond the perimeter of the hole.

***Riveting hammer*** A small hammer with a wedge-shaped face specifically designed to spread rivets.

***Set or Rivet set*** A hollow metal cylinder that is placed over the shank of a rivet after it has been inserted through the pieces to be joined. The set is given a sharp blow that compresses the layers to be joined and is then removed so the rivet may be hammered.

***Sinking*** The process of forming a three-dimensional object from sheet metal by hammering the inside surface. The object can be held on an anvil or sandbag while forming.

***Slag*** the impurities remaining after smelting ore or melting metal for casting.

***Smelting*** The process by which metal is refined from *ore* and separated from non-metallic impurities (see *slag*).

***Soldering*** A hot joining technique where an alloy with a lower melting temperature is used to join pieces of metal.

***Snarling iron*** A kind of *stake* that is used to form an object with a narrow neck from the inside. The tool is "T" shaped with the tang secured to the anvil. The object is placed over one arm of the "T", while the other is struck with a hammer. The reaction causes the arm inside the object to bounce and strike the interior of the metal object.

***Spalling*** Flaking of metal or corroded surfaces.

***Sprue*** a line of metal that joins the *jet* to the cast object

***Stake*** An upright extension of an anvil . the head of the stake is usually shaped to support and help form the shape of the metal object.

***Stamp/stamping*** A decorative technique where a design is created by hammering a metal tool that creates an impression on a metal surface.

***Stretching*** A process where an ingot of metal is forged (see *forging*) in order to extend the metal while reducing its thickness.

***Stress (Metal fatigue)*** A condition in which metal is worked to the point where it is no longer malleable and is subject to cracking. In order to restore the metal's ductility and continue working the metal must be *annealed.*

***Swage*** a negative form, similar to a mould in which metal is pressed or hammered in order to form a shape. Also known as a swedge.

***Swaging*** The process of hammering or pressing metal into a swage. Also known as swedging.

***Tang*** An extended piece of metal used for securing a tool such as a *stake, snarling iron* into a secure work surface. A tang is also the portion of knife, chisel, or other tool that is set in into a handle.

***Tinning*** Coating an object with tin. This can be done by dipping a heated object in molten tin, or by rubbing tin on the heated surface of an object.

***Tuyere*** A tubular section of a bellows that leads into the furnace.

***Valve*** A section of a mould.

# APPENDIX 2: RECIPES FOR REFRACTORY MATERIALS USED IN EXPERIMENTS

**Crucibles and exterior layers of moulds:** This is a coarse mixture designed to maximise the object's ability to withstand thermal shock. Crucibles can survive 5-7 pours before the sand vitrifies to the extent that they become soften and crack. Recipe derived from petrographic analysis done by Hillary Howard (1980)

1 part clay
1 part coarse sand
½ part chopped/sifted straw
½ part sawdust

**Inner layer of moulds:** A fine grained, porous mixture designed to give a smooth surface, or to replicate detail. Recipe provided by Dr. Holger Lonzes

1 part clay
1 part fine sand
1 part sifted grog

1 part organic matter (strained dung is the preferred medium, however shredded and pulped egg cartons are a good substitute)

Crushed and sifted charcoal and ash (enough to darken the mixture)

**Cores:** A friable material is needed so that cores for socketed or hollow objects can easily be removed. Recipe provided by Dr. Holger Lönze

1 part clay
½ part sand
1 part coarse bran

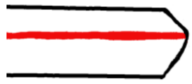
Cores can also be made from cuttlefish bone.

# APPENDIX 3: WEAR USE SCHEMATICS AND DATA

## SCHEMATIC

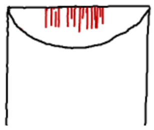
A. Casting Seam, central

B. Castingseam, off centre



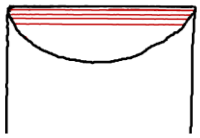
C. Rough surface as cast

D. Scratches perpendicular to top edge



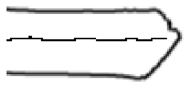
E. Scratches parallel to top edge

F. Parallel scratches evenly spaced

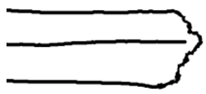


G. Random scratches

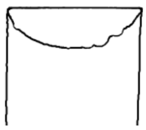
H. Dings or small dents on one facet of face



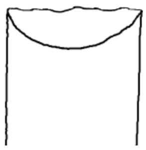
I. Dings or small dents on both facets of face



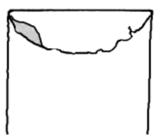
J. Dings on edge of face



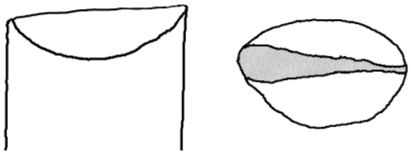
K. Damage to apex of face



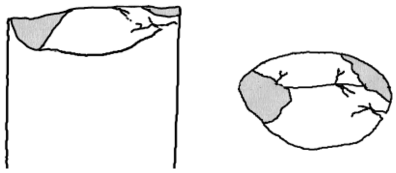
L. Damage to edges of face



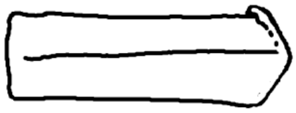
M. Asymmetrical face



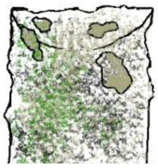
N. Deformation or cracks on face



O. Burring



P. Corrosion



## *USE WEAR ON MUSEUM OBJECTS*

| Object | Accession number | Museum | Wear | Interpretation |
|---|---|---|---|---|
| **Anvil** | 83 2-18.29 | BM | | No evidence of maintenance or wear, no corrosion, some scratches and dings |
| **Anvil** | Anvil Inshoch Wood Hoard | IN | P | cleaned |
| **Chisel** | 117.2 | WMS | P | |
| **Chisel** | 02/115 | COLEM | P | |
| **Chisel** | 02/117 | COLEM | P | |
| **Chisel** | 02/118 | COLEM | P | |
| **Chisel** | 1998 9-1 331 | BM | A P | |
| **Chisel** | 83 2-8.23 | BM | P | |
| **Chisel** | 83 2-8.24 | BM | D | |
| **Chisel** | AN 1836. p 122 no.24 | AN | P | inconclusive |

| Object | Accession number | Museum | Wear | Interpretation |
|---|---|---|---|---|
| **Chisel** | AN 1927.2460 | AN | O P | Chevron texture inside socket |
| **Chisel** | AN 1927.2460 | AN | L P | Inconclusive |
| **Chisel** | AN 1927.2465 | AN | clean | finely tapered, possibly maintained |
| **Chisel** | AN 1927.2688 | AN | P | Chisel still fairly sharp |
| **Chisel** | AN 1955.144 | AN | p | Inconclusive |
| **Chisel** | Arch 225 | WMS | P | |
| **Chisel** | DZSWS 167 | DZSWS | P | |
| **Chisel** | DZSWS 1982.39 | DZSWS | H O | |
| **Chisel** | DZSWS 1983.71.1 | DZSWS | P | |
| **Chisel** | DZSWS 1984.126.1 | DZSWS | P | |
| **Chisel** | DZSWS 1984.51 | DZSWS | clean | |
| **Chisel** | DZSWS 1987.45.2.2 | DZSWS | P | |
| **Chisel** | DZSWS 2004.429 | DZSWS | H P | |
| **Chisel** | IOW 2011-2-64 | IOW | P | |
| **Chisel** | STHEAD 207 | DZSWS | E P | |
| **Chisel** | STHEAD 312 | DZSWS | P | |
| **Chisel, possibly stamp** | 119.29.1 | NM | not cleaned | |
| **Chisel/Palstave** | 3162 | WMS | P | |
| **Chisel/palstave** | AN 1927.2688 | AN | P | Chisel still sharp |
| **Drawplate** | X22.1 | SEHS | | |

| Object | Accession number | Museum | Wear | Interpretation |
|---|---|---|---|---|
| **Drawplate** | | SEHS | | |
| **Drawplate** | | SEHS | | |
| **Hammer** | 119.28 | NM | B I P | |
| **Hammer** | 151.94 | COLEM | B O P | Corroded face |
| **Hammer** | 276.55 | SOUMS | A D E P | A lot of abrasion |
| **Hammer** | 276.56 | SOUMS | P clean | Is it a hammer? Wedge shaped face, could be a stake, distinct apex |
| **Hammer** | 02/142 | COLEM | AB P | Too corroded |
| **Hammer** | 02/143 | COLEM | B D E F O P | Appears that the hammer face was maintained before deposition |
| **Hammer** | 02/144 | COLEM | N O P | Appears heavily used, severe burring, fragment |
| **Hammer** | 199 2-6.27 | BM | | No face, no mouth, is it a hammer? |
| **Hammer** | 1961 10.6 33 | BM | B D E O P | Hammer faces appear to have been maintained. Symmetrical face |
| **Hammer** | 1987.45.1 | DZSWS | I K M P | Asymetrical face appears higher on PL, although corroded |
| **Hammer** | 1998 9.1.224 | BM | B P | Worn rounded face |
| **Hammer** | 1999 1.1.225 | BM | A L O P | Angled face |
| **Hammer** | 2000 1.1.226 | BM | A M P | Asymmetrical face |
| **Hammer** | 2001 06.01.1 | BM | B O P | Has loop, possibly cast from modified axe mould. Face is modified to have triangular shape |
| **Hammer** | 1998.9.1.227 | BM | D K P | Wedge shaped face, corroded, fragment |
| **Hammer** | 1998.9.1.228 | BM | E O P | Might not be a hammer |

| Object | Accession number | Museum | Wear | Interpretation |
|---|---|---|---|---|
| **Hammer** | 2006 0203.3 | BM | P | Very corroded |
| **Hammer** | 33 4.26. 137 | BM | P | Very corroded |
| **Hammer** | 42 A | TM | F O | |
| **Hammer** | 52 06.26 88 | BM | B D F I K M | Appears that the hammer face was maintained before deposition. Two sets of fine parallel scratches evenly spaced on edge of narrow facet of the face. Long parallel/perpendicular scratches on the wider facet of the face. Casting seams in interior are on top and bottom rather than sides Asymmetrical face apex higher at PL |
| **Hammer** | 83 02.18.20 | BM | A E H | Slanted face |
| **Hammer** | 83 02.18.21 | BM | H K L | Slanted face |
| **Hammer** | A:2002.26.1 | IOW | P | Too corroded |
| **Hammer** | AN 1836 p 122.23 | AN | F P | Scratches could be maintenance, but hammer is very corroded |
| **Hammer** | AN 1927.2463 | AN | B D F | inconclusive |
| **Hammer** | AN 1927.2511 | AN | D F G L M P | Apex poorly defined and worn on PL |
| **Hammer** | AN 1927.2512 | AN | B P | Face corroded |
| **Hammer** | AN 1927.2662 | AN | A C J P | Very heavy, rounded face, |
| **Hammer** | AY 407.2 | WMS | D F O P | Heavily burred, heavily corroded |
| **Hammer** | IC5A.5 | SSWM | P | Peaked face, very symmetrical |

| Object | Accession number | Museum | Wear | Interpretation |
|---|---|---|---|---|
| **Hammer** | IOW 2010-19-2 | IOW | P | Too corroded |
| **Hammer** | NCM 1949.209 | NCM | J M O P | Tanged hammer , unusual dings and dents all over body, very burred |
| **Hammer** | NWHCM : 1845.70.16 | NCM | B O P | Corroded face |
| **Hammer** | NWHCM : 1984.1.5 | NCM | B F M O | Beautiful condition, asymmetrical face apex pushed up on PL (apex is 10.5 mm from top edge on PR and 7 mm on PL) |
| **Hammer** | NWHCM: 1993 1981.5.A | NCM | B F G M P | Faceted, asymmetrical face but corroded (apex is 7.4 mm from top on PR and 6.4 mm on PL), flash broken off, not sanded |
| **Hammer** | NWHCM :2003.171.1-6 | NCM | B F M | Asymmetrical face, apex pushed up on PL |
| **Hammer** | SOUMS 72 | SOUMS | P | Very corroded |
| **Hammer** | X20.1 | SEHS | A D J I P | Face pitted but scratches visible |
| **Hammer** | X20.2 | SEHS | B L M N O P | very uneven well used surface, heavily burred |
| **Hammer** | X20.3 | SEHS | A M N O P | Very uneven well used surface, heavily burred |
| **Hammer** | | IM | P | Very corroded |
| **Hammer** | J93.518 | WPM | P | Very corroded and pitted |
| **Hammer** | 1918 7-9.2 | CPMR | B P | Very corroded and pitted, offset socket |
| **Hammer** | 1918 7-9.3 | CPMR | P | Very corroded and pitted |
| **Hammer** | J93.518 | WPM | A F G | Face corroded and pitted |

## USE WEAR ON EXPERIMENTAL TOOLS

| ID Number | Object | Use | Wear | Experiment | Notes |
|---|---|---|---|---|---|
| **0** | Chisel | Carving stone mould | F D | 3 | Heavily burred on striking end. Hammer marks on length of tool body from straightening by hammering. |
| **0** | Chisel | Chasing | | 8 | no change |
| **1** | Chisel | Not used | | | |
| **2** | Chisel | Carving stone mould | F D O | 3 | Heavily burred on striking end. Also burred on both sides of blade |
| **3** | Chisel | Chasing | | 8 | no change |
| **4** | Chisel | Not used | | | |
| **5** | Chisel | Chasing | | 8 | no change |
| **6** | Chisel | Not used | | | |
| **7** | Chisel | cutting tin/lead ingot | | 5 | no change |
| **8** | Chisel | Not used | | | |
| **9** | Chisel | Chasing | | 8 | |
| **10** | Chisel | | | | |
| **A1** | Hammer | Forging chisel blade | I K | 4 | Hammer face smoothed, apex rounded off. Scratches remain at edges |
| **A2** | Hammer | Carving stone mould | I K O | 3 | Dings and mottled surface over all the face. |

| ID Number | Object | Use | Wear | Experiment | Notes |
|---|---|---|---|---|---|
| **A2** | Hammer | Sharpening axe | K M O | 2 | Face was smoothly rounded, with little evidence of apex. Some burring at lower edge. Upper PR corner of face pushed upward |
| **A2** | Hammer | Forming bronze bowl | O | 6 | Face was smoothly rounded, with little evidence of apex. Some burring at lower edge. |
| **C1** | Hammer | Planishing bronze bowl | | 7 | No change to hammer face |
| **C1** | Hammer | Chasing | I J | 8 | Dings on both facets of hammer face |
| **C1** | Hammer | Maintenance | D E F | 9 | 1/2 hour sanding using coarse gritstone obtained from Gardom's Edge<br><br>Coarse and fine parallel scratches |
| **F1** | Hammer | Forging bronze bar stock | F G K M N O | 4 | Burred upper edge, rounded lower edge of apex. Distortion (rippling) of metal on apex |
| **F1** | Hammer | Maintenance | | 9 | Sanded with gritstone and then finer basalt. |

# Appendix 4: Inventory of tools examined organised by type

| Object | Accession Number | Museum | Hoard/ Single find | Type | Notes |
|---|---|---|---|---|---|
| **Anvil** | 1927 2051 | AN | | Beaked | Top is slanted |
| **Anvil** | | IM | Inshoch Wood Hoard | Beaked | |
| **Anvil** | 1927 2322 | AN | | Complex | Unequal peaked top. Back has series of slots (possibly for drawing wire). Beak is square rather than round |
| **Anvil** | 83 2-8 19 | BM | Lusmagh Hoard | Complex | Has two holes on side and two on longer beak (drawplates), peaked top |
| **Awl** | 52 G-26 89 | BM | Thorndon Hoard | | |
| **Awl** | DZSWS 1984.126.1 | DZSWS | Single find | | |
| **Bone handle** | DZSWS:STHEAD 95a | DZSWS | Single find | | Bone handle for chisel DZSWS:STHEAD 95 (also accessioned as 667) |
| **Bone handle** | STHEAD 171 | DZSWS | Single find | | Bone handle for chisel STHEAD 167 |
| **Bronze mould for socketed axe** | 1927 2490 | AN | Isle of Harty Hoard | | Matches axes in hoard |
| **Bronze mould for socketed axe** | 1927 2498 | AN | Isle of Harty Hoard | | Matches axe 2499 |
| **Bronze mould for socketed axe** | 1927 2501 | AN | Isle of Harty Hoard | | Matches axes 2502, 2503. Could 2490 have been made first, axes cast from mould 2497 and made from them (slightly smaller) |
| **Bronze mould for socketed axe** | 2003.171.1-6 | NCM | Hevingham Hoard | | Does not match axes in hoard |
| **Bronze mould for socketed axe** | 2003.171.1-6 | NCM | Hevingham Hoard | | |
| **Bronze mould for socketed axe** | IC5A.6 | SSW | Donhead St. Mary's Hoard | | Half Mould. Pristine, dark grey metal. |
| **Bronze mould for socketed axe** | IC5A.6 | SSW | Donhead St. Mary's Hoard | | Half Mould. Pristine, dark grey metal. Little corrosion inside, clean outside. Raised lip around seam. |
| **Bronze mould for socketed axe** | J93.514 | WPM | Roseberry Topping Hoard | | Two valves, excellent condition |

| Object | Accession Number | Museum | Hoard/ Single find | Type | Notes |
|---|---|---|---|---|---|
| **Bronze mould for socketed gouge** | 1927 2507 | AN | Isle of Harty Hoard | | Matches gouge 2509 |
| **Bronze mould for spear** | 63/1994 | TM | | | Spear is asymmetrical |
| **Chisel** | 1836 p122 no 24 | AN | | Blade fragment | |
| **Chisel** | 02/115? | COLEM | Grays Thurrock Hoard | Coombs Type 1a | |
| **Chisel** | 02/118 | COLEM | Grays Thurrock Hoard | Coombs Type 2d | Or a bit of flat metal |
| **Chisel** | BROOKE 321 | DZSWS | Single find | Coombs Type 4a | |
| **Chisel** | 1927 2373 | AN | Single find / Mildenhall | Flat axe type | |
| **Chisel** | DZSWS 167 | DZSWS | Single find | Flat axe type | |
| **Chisel** | DZSWS:STHEAD 95 | DZSWS | Single find | Flat axe type | Blade for handle DZSWS:STHEAD 95 (also accessioned as 666) |
| **Chisel** | STHEAD 207 | DZSWS | Single find | Flat axe type | |
| **Chisel** | STHEAD 312 | DZSWS | Single find | Flat axe type | |
| **Chisel** | STHEAD 312a | DZSWS | Single find | Flat axe type | |
| **Chisel** | 1918.7.9.4 | CPMR | Kilnhurst | Socketed | |
| **Chisel** | 1927 2465 | AN | | Socketed | |
| **Chisel** | 1955 144 | AN | Highworth | Socketed | Chevron texture inside socket |
| **Chisel** | 83 2-18 25 | BM | Lusmagh Hoard | Socketed | |
| **Chisel** | 1927 2462 | AN | Reach Fen Hoard | Tanged | |
| **Chisel** | 2009.237.3 | NCM | West Acre Hoard | Tanged | |
| **Chisel** | DZSWS 1984.51 | DZSWS | Single find | Tanged, flared blade, Coombs Type c stop | |
| **Chisel** | 83 2-18 23 | BM | Lusmagh Hoard | Trunnion | Blade has polished edge |

| Object | Accession Number | Museum | Hoard/ Single find | Type | Notes |
|---|---|---|---|---|---|
| **Chisel** | 83 2-18 24 | BM | Lusmagh Hoard | Trunnion | Fine edge |
| **Chisel** | 117.2 | WMS | Froxfield Barrow | | |
| **Chisel** | Arch 225 | WMS | Single find | | |
| **Chisel** | J93.519 | WPM | Roseberry Topping Hoard | | Resembles spearpoint |
| **Chisel** | #VALUE! | SOUMS | Vange Hoard | | Fragment |
| **Chisel** | 1927. 2460 | AN | Reach Fen Hoard | Socketed | |
| **Chisel** | 1836 p122.24 | AN | Burgess Meadow Hoard | Tanged | |
| **Chisel/ axe** | 1927 2460 | AN | | Socketed | |
| **Chisel / palstave** | 1927 2687 | AN | Dorchester | | |
| **Chisel/ palstave** | 3162 | WMS | | | |
| **Chisel/ palstave** | 1927 2688 | AN | | | |
| **Chisel** | 1927. 2460 | AN | Reach Fen Hoard | Socketed | |
| **Chisel** | 1836 p122.24 | AN | Burgess Meadow Hoard | Tanged | |
| **Chisel (?)** | 1998 9-1 331 | BM | Salisbury Hoard | Straight | Polished face. Possible chasing tool |
| **Chisel (?)** | 02/117? | COLEM | Grays Thurrock Hoard | | Blade fragment chisel or axe? |
| **Chisel (?)** | 1836 p122-25 | AN | Burgess Meadow Hoard | | |
| **Drawplate** | X22.1 | SEHS | Isleham Hoard | | 6 holes |
| **Drawplate** | X22.2 | SEHS | Isleham Hoard | | 7 holes |
| **Drawplate** | X22.3 | SEHS | Isleham Hoard | | Fragment with 1 hole |
| **Drill bit** | 1981.11-1.4 | BM | Runnymede | | |
| **Faceted awl** | DZSWS 1009 | DZSWS | Single find | | |
| **Graver** | DZSWS 1983.71.1 | DZSWS | Single find | | |
| **Graver** | DZSWS 1987.45.2 | DZSWS | West Kennet Longbarrow hoard | | |

| Object | Accession Number | Museum | Hoard/ Single find | Type | Notes |
|---|---|---|---|---|---|
| **Hammer** | 72 | SOUMS | Vange Hoard | 1 | |
| **Hammer** | 151.94 | COLEM | Hatfield Broad Oak Hoard | 1 | |
| **Hammer** | 02/142 | COLEM | Grays Thurrock Hoard | 1 | Corroded face. Flat face (planishing?) |
| **Hammer** | 119-28 | NM | Norththampton Hoard | 1 | |
| **Hammer** | 1918.7.9.2 | CPMR | Kilnhurst | 1 | |
| **Hammer** | 1927 2511 | AN | Isle of Harty Hoard | 1 | Face slightly lopsided |
| **Hammer** | 1927 2512 | AN | Isle of Harty Hoard | 1 | |
| **Hammer** | 1961 10.6 33 | BM | Minnis Bay | 1 | |
| **Hammer** | 1984.1.5 | NCM | Bunwell Hoard | 1 | |
| **Hammer** | 1993 198.1.1:A | NCM | Cranwich Hoard | 1 | |
| **Hammer** | 1998 1-1 224 | BM | Salisbury Hoard | 1 | Face is flattened |
| **Hammer** | 2003.171.1-6 | NCM | Hevingham Hoard | 1 | |
| **Hammer** | 2006 2-3 3 | BM | Single find Isle of Wight | 1 | |
| **Hammer** | 52 G-26 88 | BM | Thorndon Hoard | 1 | Casting seams on interior opposite to that of exterior |
| **Hammer** | A:2002.26.1 | IOW | Kirkton Hoard | 1 | |
| **Hammer** | AY407.2 | WMS | Hambledon | 1 | |
| **Hammer** | DZSWS 1987.45.1 | DZSWS | West Kennet Longbarrow hoard | 1 | |
| **Hammer** | S1988.121.18 / 1988 9-1 226 | BM | Salisbury Hoard | 1 | Has decoration similar to Taunton hammer. Off centre socket |
| **Hammer** | X20.3 | SEHS | Isleham Hoard | 1 | Fragment of face end of hammer, heavily used and burred |
| **Hammer** | 1964 12-1 136 | BM | Fourdan, France | 2 | |
| **Hammer** | IC5A.5 | SSWM | Donhead St. Mary's Hoard | 2 | Working surface very corroded |
| **Hammer** | 02/143 | COLEM | Grays Thurrock Hoard | 3 | Face abraded in antiquity. Burred face. |
| **Hammer** | 1927 2662 | AN | Single find / Lakenheath | 3 | |

| Object | Accession Number | Museum | Hoard/ Single find | Type | Notes |
|---|---|---|---|---|---|
| **Hammer** | J93.518 | WPM | Roseberry Topping Hoard | 3 | |
| **Hammer** | 83 2-18 21 | BM | Lusmagh Hoard | 4 | |
| **Hammer** | 83.2-18.20 | BM | Lusmagh Hoard | 4 | |
| **Hammer** | M 18-4 / 1998 9-1 225 | BM | Salisbury Hoard | 4 | |
| **Hammer** | 1918.7.9.3 | CPMR | Kilnhurst | 5 | |
| **Hammer** | S1988.1237 / 1998 9-1 227 | BM | Salisbury Hoard | 5 | Fragment |
| **Hammer** | X20.2 | SEHS | Isleham Hoard | 1 (?) | Fragment of face end of hammer, heavily used and burred |
| **Hammer** | 2001 6.1 1 | BM | Salisbury Hoard | 1 (face greatly modified) | Has loop. Short side of face has corners removed to make an almost triangular face |
| **Hammer** | 276.55 | SOUMS | Leigh II Hoard | 1a | |
| **Hammer** | 1836 p122-23 | AN | Burgess Meadow Hoard | 1a | |
| **Hammer** | 1845.70.16 | NCM | Carleton Rode Hoard | 1a | |
| **Hammer** | 1927 2463 | AN | Reach Fen Hoard | 1a | |
| **Hammer** | 33 4.26 137 | BM | Minster Hoard | 1a | Heavily corroded |
| **Hammer** | 42 A | TM | Taunton Workhouse Hoard | 1a | |
| **Hammer** | X20.1 | SEHS | Isleham Hoard | 1a | |
| **Hammer** | | IM | Inshoch Wood Hoard | 1a | |
| **Hammer** | 02/144 | COLEM | Grays Thurrock Hoard | Fragment | Fragment |
| **Hammer** | 1149.209 | NCM | Beachamwell | Tanged | Unusual hammer, heavily burred. Might also have been used as a stake |
| **Hammer (?)** | S1998 121.86 / 1998 9.1 228 | BM | Salisbury Hoard | Double faced tool with ring in middle | |
| **Hammer (?)** | 1922 2-6 19 | BM | Swalecliffe Hoard | Fragment without face or mouth | |
| **Hammer (?)** | 1927 2-6 27 | BM | Swalecliffe Hoard | Fragment without face or mouth | |

| Object | Accession Number | Museum | Hoard/ Single find | Type | Notes |
|---|---|---|---|---|---|
| **Hammer face** | 276.56 | SOUMS | Leigh II Hoard | 5 | |
| **Mortising Chisel** | 119-29 | NM | Northampton Hoard | | Could be stamp or repousse tool |
| **Punch** | DZSWS 1982.39 | DZSWS | Single find | | |
| **Rivet snap (?)** | 83 2-18 26 | BM | Lusmagh Hoard | | Remains of wooden handle secured by 4 pins |
| **Stone mould** | 1927 2723 | AN | | Side looped spear | |
| **Stone mould** | 1927 2897 | AN | | Side looped spear | |
| **Stone mould** | 1927 2724 | AN | | Spear | |
| **Stone mould** | 1927 2895 | AN | | Spear | |
| **Stone mould** | 1886 5765 | AN | | | Fragment of mould from palstave or chisel |
| **Stone mould** | 1927 2898 | AN | | | Carved for spearhead or knife on one side, the other has two chisels and an arc |
| **Whetstone** | 1927 2518 | AN | Isle of Harty Hoard | | Drilled (to hang from cord?) |
| **Whetstone** | IC5A.7 | SSWM | Donhead St. Mary's Hoard | | |

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ADS = Archaeological Data Services Database
BM = British Museum
PAS = Portable Antiquities Scheme Database

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| Hoard or Object | Reference |
|---|---|
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| --- | --- |
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|---|---|
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# APPENDIX 5 MTR: AN INVENTORY OF MINIMUM TOOLS REQUIRED FOR METALWORKING

## MTR: A MEANS FOR UNDERSTANDING METALWORK AND METALWORKING TOOLS

While no list of tools can be exhaustive, this study seeks to provide a basis for the those unfamiliar with metalsmithing practices to understand the tools and materials necessary for various metalworking tasks. This method does not intend to be exhaustive, providing an inventory of every type of tool that could have possibly used in the Bronze Age. Rather it is intended as a means to readily understand metalworking processes as represented by tools, materials, and metal objects found in the Bronze Age in Britain. Many tools such as hammers and chisels are easily identifiable. However, less familiar tools such as snarling irons and rivet snaps could be part of museum collections as unidentified objects.

The method will also be valuable to the experimental archaeologist who is interested in recreating Bronze Age metalsmithing using techniques and materials used at the time. While not all of the tools and materials have been recovered from Bronze Age contexts, some objects such as bellows, are necessary for the task to be completed. By examining objects and tools from the archaeological record and understanding basic metalsmithing procedures, the experimenter can replicate a Bronze Age tool kit as closely as possible in order to conduct experiments.

By becoming aware of the range of metalworking tools and their purpose, both the tools and the objects they were used to make can together bring about a greater understanding of the processes of metalworking in the Bronze Age.

## HOW THIS CHART WORKS

The chart is designed to introduce the processes of various metalworking tasks for those unfamiliar with metalsmithing. For example, if a fragment of sheet metal was found, the technique by which it was made would be either forging or rolling. Metallurgical analysis could confirm how the sheet metal was formed. However, if there were hammers found with the metal, it could be an indication that the sheet metal was forged.

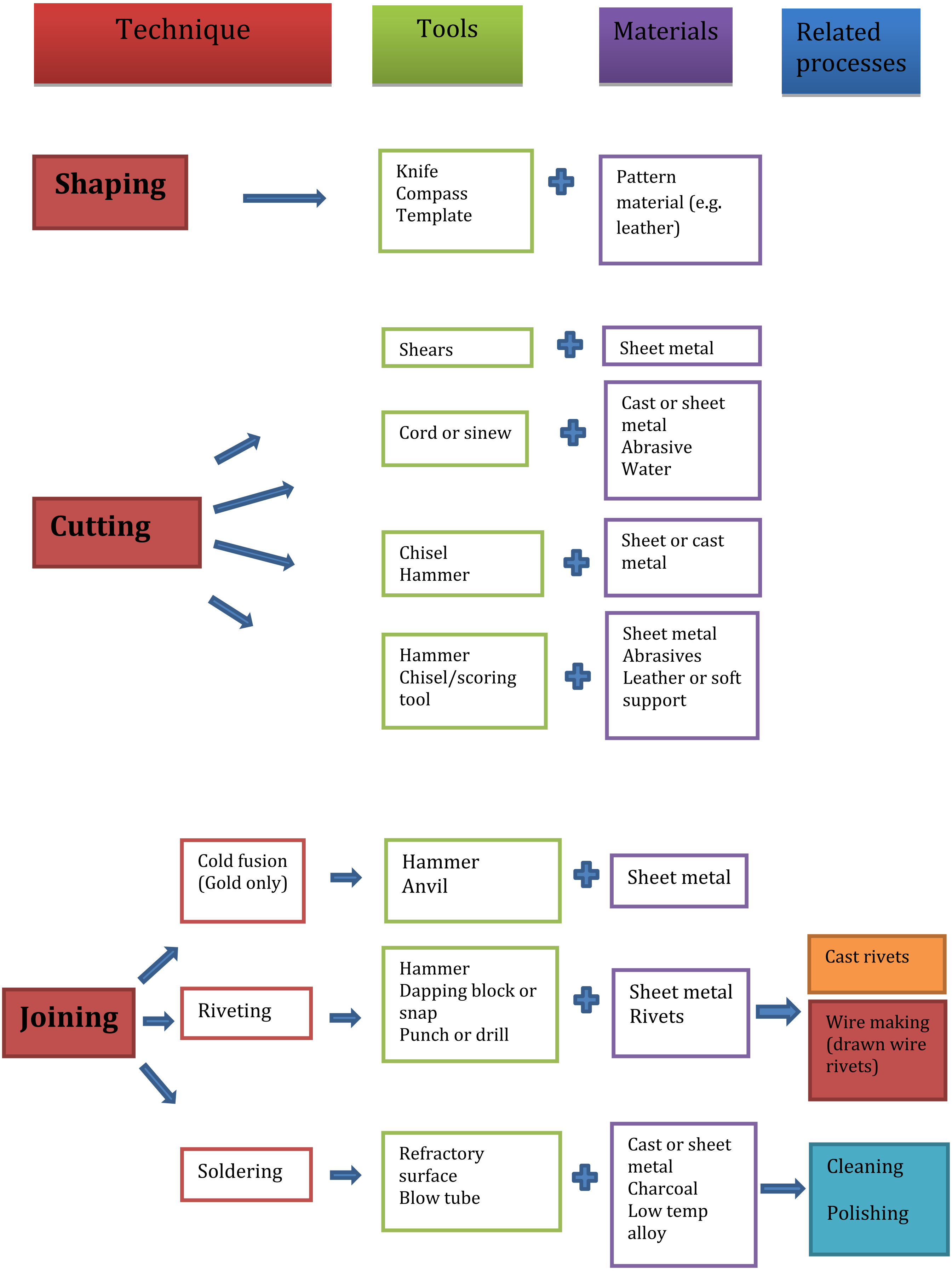
Using sheet metal as an example, the tool category of the chart below indicates that an anvil and a hammer are needed to forge sheet metal. In the materials category, the only entry is for the raw metal itself. In the final category we have related processes. Here it indicates that the metal must be annealed, cleaned and polished. Looking farther down the list of techniques to "Annealing" and checking the tools and materials need for that process indicate that a hearth is needed for annealing. Tongs or leather gloves are also needed since annealing heats the metal to a point where it cannot be held in bare hands. Since tongs can be made of wood, they and leather gloves would not survive in the archaeological record. However it is important to recognise all aspects of the craft, not only because there might be the extremely rare event where these objects might be recovered, but also to recognise the crossover between crafts, in this case leatherworking and woodworking.

The chart can also be used to recognise a tool by associated tools and materials. For instance an anvil with holes for drawing wire would indicate wire making, and so other tools associated with wire making or objects that incorporate wire might also be recognised if they were combined in a hoard.

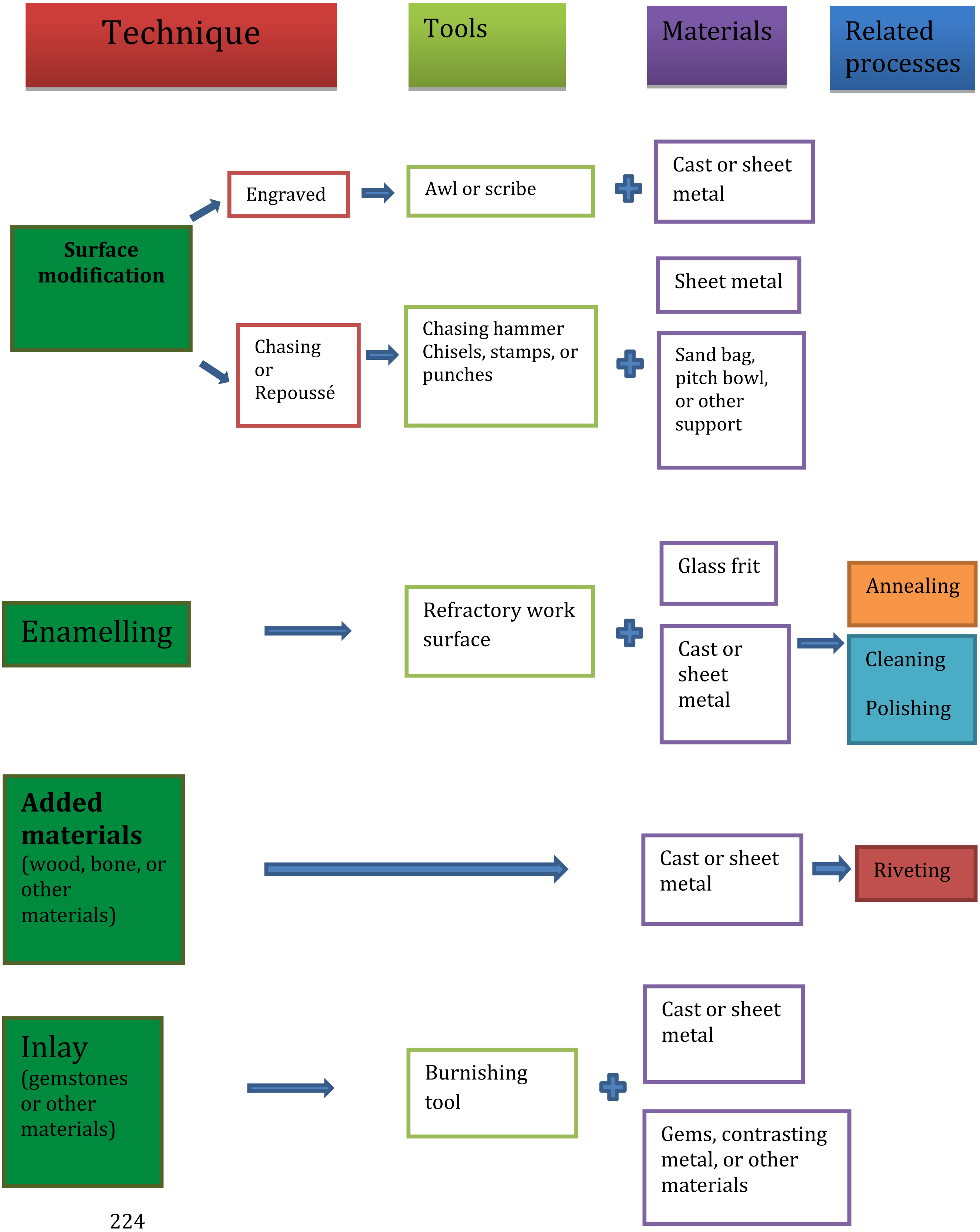
It is hoped that having a systematic approach to understanding all aspects of metalworking will be of benefit to archaeology and provide them means for recognising tools and materials in the British Bronze Age.

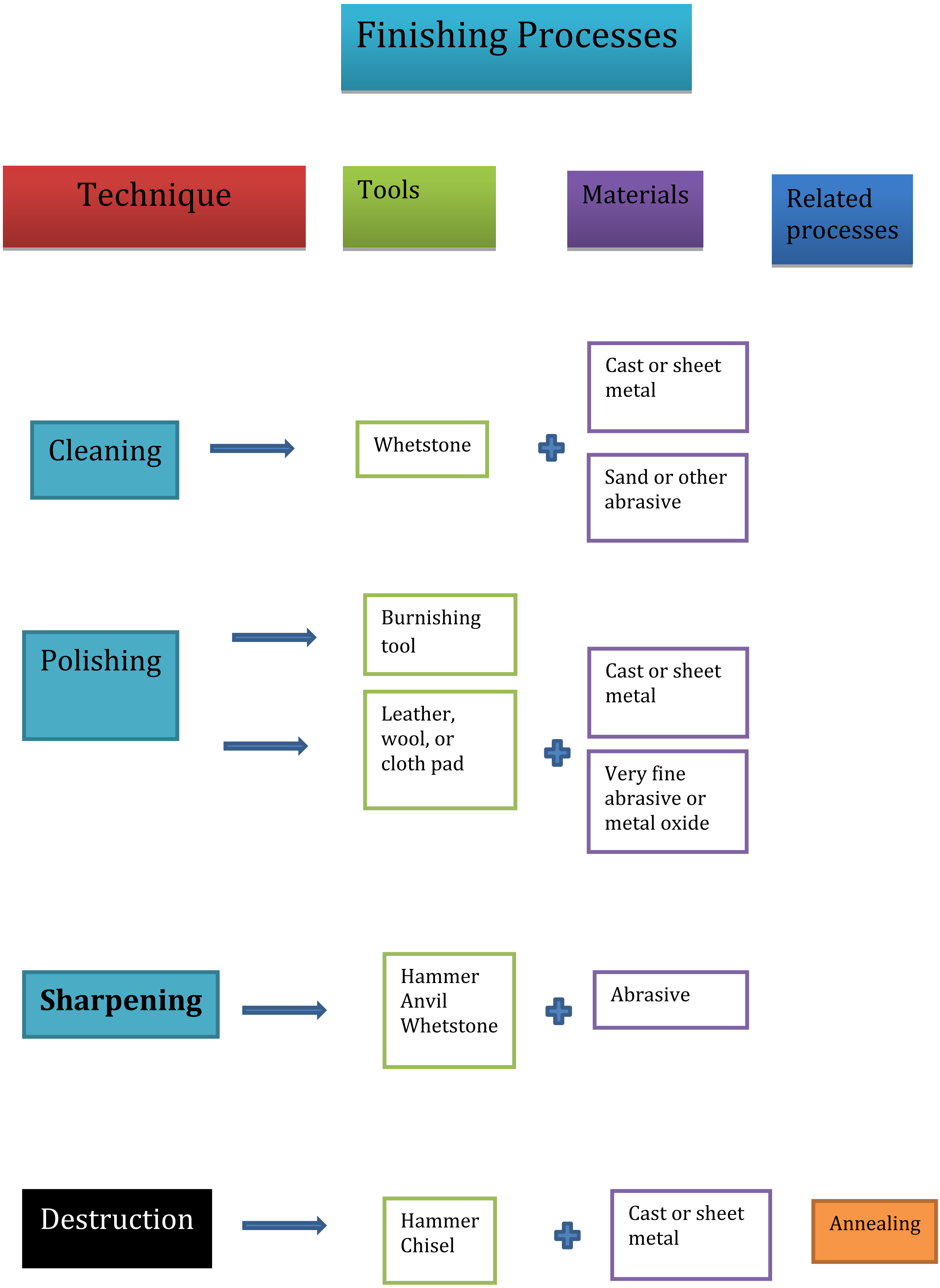
# Forming Processes

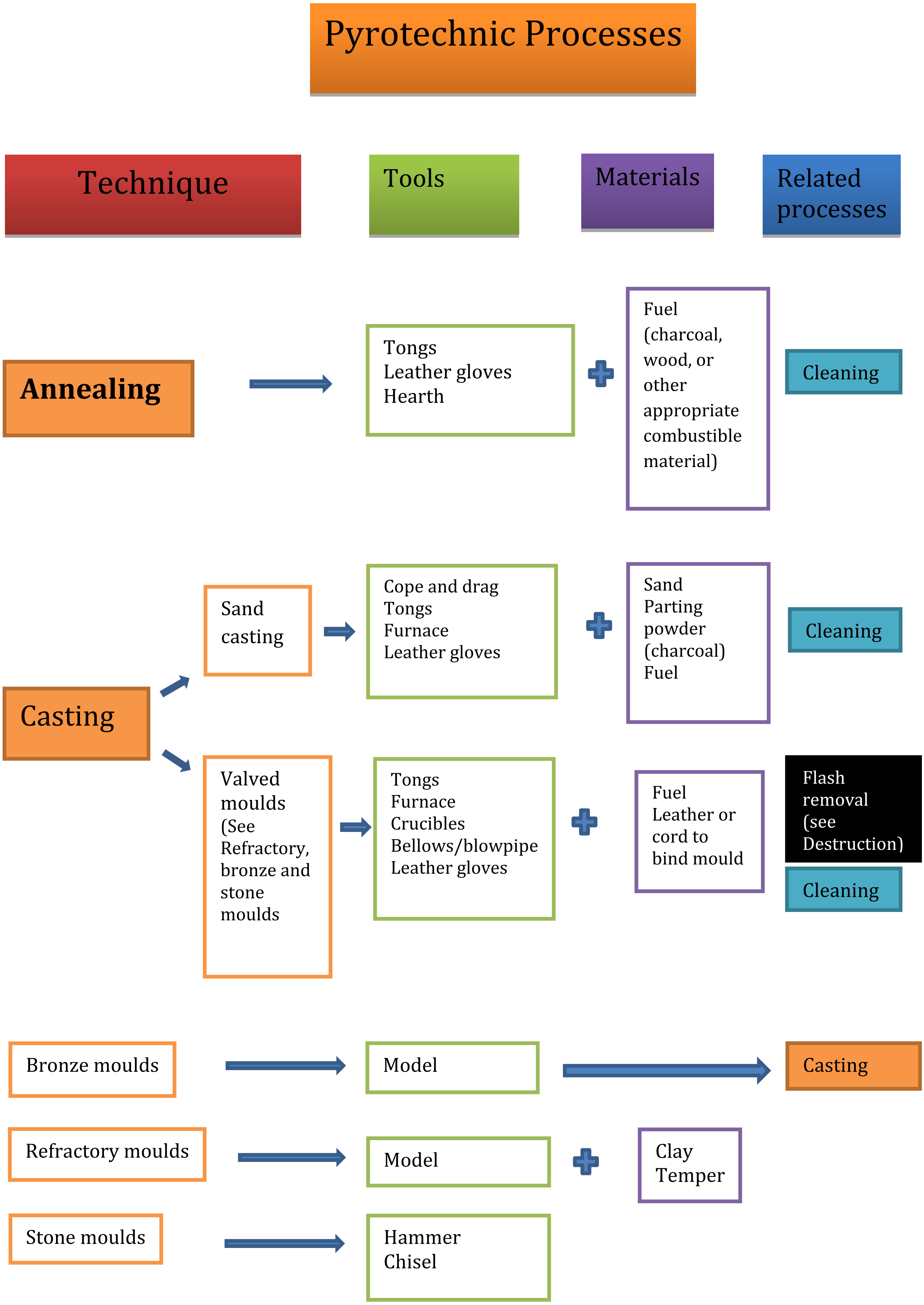
| Technique | Tools | Materials | Related processes |
|---|---|---|---|
| **Sheet metal** → Forging | Anvil<br>Forging hammer<br>Planishing hammer | Cast metal | Annealing<br>Cleaning<br>Polishing |
| **Sheet metal** → Rolling | Anvil<br>Rolling stone | Cast metal | Annealing<br>Cleaning<br>Polishing |
| **Forming (3D) Raising** | Anvil, stake. Swage or snarling iron (choice determined by type of object being made)<br>Forming hammer<br>Planishing hammer<br>Mandrel (for rings and bracelets) | Sheet metal | Annealing<br>Cleaning<br>Polishing |
| **Forming (3D) Sinking** | Forming hammer<br>Planishing hammer<br>Sandbag | Sheet metal | Annealing<br>Cleaning<br>Polishing |
| **Wire Making** | Hammer<br>Swage<br>Clamp or vice<br>Drawplate | Sheet metal | Annealing |


Technique
Tools
Materials
Related processes
Shaping
Knife
Compass
Template
Pattern material (e.g. leather)
Shears
Sheet metal
Cord or sinew
Cast or sheet metal
Abrasive
Water
Cutting
Chisel
Hammer
Sheet or cast metal
Hammer
Chisel/scoring tool
Sheet metal
Abrasives
Leather or soft support
Cold fusion (Gold only)
Hammer
Anvil
Sheet metal
Joining
Riveting
Hammer
Dapping block or snap
Punch or drill
Sheet metal
Rivets
Cast rivets
Wire making (drawn wire rivets)
Soldering
Refractory surface
Blow tube
Cast or sheet metal
Charcoal
Low temp alloy
Cleaning
Polishing

# Decorative Processes




Finishing Processes
Technique
Tools
Materials
Related processes
Cleaning
Whetstone
Cast or sheet metal
Sand or other abrasive
Polishing
Burnishing tool
Leather, wool, or cloth pad
Cast or sheet metal
Very fine abrasive or metal oxide
Sharpening
Hammer
Anvil
Whetstone
Abrasive
Destruction
Hammer
Chisel
Cast or sheet metal
Annealing


Pyrotechnic Processes
Technique
Tools
Materials
Related processes
Annealing
Tongs
Leather gloves
Hearth
Fuel (charcoal, wood, or other appropriate combustible material)
Cleaning
Casting
Sand casting
Cope and drag
Tongs
Furnace
Leather gloves
Sand
Parting powder (charcoal)
Fuel
Cleaning
Valved moulds (See Refractory, bronze and stone moulds
Tongs
Furnace
Crucibles
Bellows/blowpipe
Leather gloves
Fuel
Leather or cord to bind mould
Flash removal (see Destruction)
Cleaning
Bronze moulds
Model
Casting
Refractory moulds
Model
Clay
Temper
Stone moulds
Hammer
Chisel

# INDEX

## A



## B



## C

## H



## I



## K

## L



## M



## N



## O

## P



## R



## S

## T



## U



## V