Beyond the Crucible:

An Integrated Approach to Primary Copper Production in the Early Bronze Age

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Abstract

Primary evidence for copper smelting remains vastly underrepresented in the British Bronze Age. The analysis of recovered copper and copper alloy objects has built a database of metal types and isotopic signatures, but has been unable to penetrate the archaeological record to pinpoint the contexts of primary production. This thesis is an exploration of the context of primary copper production in the Early Bronze Age in Britain.

The reduction of mineral ore to copper metal may occur within a furnace or crucible, but primary metallurgy is more than a chemical process; it is a social practice that is embedded in the landscape. As such, metallurgy draws together skilled individuals and chosen resources at specific locations and at certain times. Recognizing the spatiality of metallurgical processes opens up new opportunities for archaeological investigation and new ways of addressing longstanding problems in the study of British metallurgy. The methodology discussed within this thesis utilizes a combination of visual, geochemical, and geophysical survey within the hinterland of an identified Early Bronze Age mineral extraction site.

The methodology is examined using a case study. Ecton in North Staffordshire has been radiocarbon dated to the Early Bronze Age (Barnatt and Thomas, 1998) and provided a testing ground for the proposed methodology. A nested landscape approach was used to maximise the survey area within the landscape surrounding the Early Bronze Age mines. Stage one involved geochemical survey, which was conducted using portable X-ray Fluorescence (pXRF), and geophysical survey, conducted with a fluxgate gradiometer. Survey results were tested through excavation. The later stages focused on a wider landscape survey and involved desk based research, visual survey, and GIS analyses to situate the mines within the existing Early Bronze Age landscape. The results of this fieldwork contribute to the discussion of Early Bronze Age copper production as a social process embedded within an appropriate landscape.

Declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning

Copyright Statement

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1. Introduction

1.1. Introduction to the Problem

This thesis is an exploration of the context of primary copper production from the first millennium of metal production and use in Britain. Primary copper production refers to the initial creation of the metal and incorporates the stages of production from the collection raw materials, the extraction of metal bearing minerals, and ultimately the smelting of those minerals to produce copper metal.

In addressing primary metal production this thesis identifies two distinct issues. The first is the dearth of evidence for the production of copper metal whilst the second is the theoretical perspective that continues to underpin many studies of metallurgy in Britain; specifically, the emphases on the production of metal as technology and therefore not necessarily embedded within the social sphere. This perspective is rooted in the work of Childe (McNairn 1980) and fluoresced under the scientific focus of "The New Archaeology". While this trend has begun to change, owing in part to studies such as that undertaken at the Great Orme by Emma Wager (Wager 2001b), there remains a perceptual separation between the men and metal of the Early Bronze Age .

Though long heralded as a significant and important development in human history (Barber 2003; Childe 1930; 1944; 1951; 1957; 1962), metal production, and specifically primary production, has yet to be fully integrated into discussions of the circulation and use of metalwork as well as Bronze Age life ways and social reproduction. This is in large part due to the relative scarcity of evidence pertaining to the production of metal over the course of the first millennium of metal production and use. Fieldwork has to date focused on the identification and dating of Bronze Age mines in England and Wales and very little field led research has been aimed at addressing the complex issue of metal production.

This has led to programs of analysis intended to enlighten aspects of copper production through the analysis of recovered from their depositional contexts and approaches which tend to address metallurgical in primarily technological terms (Craddock 1980; 1989; 1995; Tylecote 1986; 1987). This emphasis on technology prioritizes 'functional, utilitarian, and logical' interpretations (Childe 1947; Wager 2001b) and maintains a Childean separation of a conceptualized technology from socially embedded production.

The evidence for the production of metal is deeply under represented in Britain with little field based researched considering the perceived impact that metal production and metalwork has had within archaeological theory and re-constructions of Bronze Age society. Traditional research agendas have focused on the origin and distribution of metalwork but have neglected the evidence for past metal making processes (O'Brien 2004; Timberlake 2001b; 2009 are notable exceptions).

There is not a total absence of evidence for the activities involved in primary metallurgy in Britain. There are a number of mining sites as well as some evidence for the initial processing of extracted copper ores in both England and Wales. However, there is almost no direct evidence for copper smelting in Britain. The primary evidence for the smelting of ore to create metal is the by-product slag, which is ubiquitous on smelting sites in other regions.

1.1.1. Production: Craft versus Technology

Part of the problems faced by those intent on investigating metallurgy within a Bronze Age context is the language in which this practice is couched and the concepts that are in built. Technology specifically, both historically and within this specific context, portrays a concept of production wherein the knowledge and acts involved are abstracted from the individual and wider social context. It therefore becomes possible to examine the processes involved in metal production as distinct entities neither acted upon nor influencing the social sphere.

The traditional approach employed by archaeometallurgists when addressing the making of metals in prehistory, and copper in particular, is to try and identify the technological process resulting in the transformation of ore to metal. However, this approach limits the importance of choice and the metallurgist and presents an incomplete picture of production with the primary focus on the resultant objects. Recent years have seen a growing movement to recognize the social context of and interaction with technological processes (Childs 1999; Dobres 2000; Doonan 1999; Giles 2007; Haaland 2004; Lemonnier 1993; Ottaway 2001; Pfaffenberger 1992); however, there remains a stigma attached to the use of technology in prehistory that is partially a result of an inability to satisfactorily define the term and its application (Ingold 2000: 296-298).

The word 'technology' is a neologism; it entered the English vocabulary in the seventeenth century (Cardwell 1973; Ingold 2000) to describe the scientific innovations of the age of reason leading into the scientific and industrial revolutions (Ingold 2000; Mitcham 1979). It is a term that describes concepts of production that divorces and compartmentalizes design, production and completed object, where the designer is not necessarily involved with the manufacture process or the final object. A technological focus prioritizes the completed object and marginalizes the skill of the producer and choices made in response to social or material demands. The interaction between producer and materials is ignored and skill or familiarity with material properties is not acknowledged.

By examining the production process as a craft, not a technology, it invokes a skilled practitioner and a focus on the interaction between the craftsperson and the materials. Design, production and outcome become intimately linked and fluidity within the process allows for and represents choices made by the craftsperson. The tasks of mining, beneficiation and smelting can be recognized as skilled practices that are dependant on a familiarity with the specific materials and processes. Refocusing on the choices of the craftsperson in relation to the material by acknowledging the making of metal as a craft, or a skilled practice, gives greater scope for the investigator to examine with the social context, organization and material needs of the series of tasks involved.

Rather than considering primary metal production as a technological process this thesis will approach it as a craft undertaken by skilled practitioners. It will engage with the *chaîne opératoire* of metal production and draw together evidence from a number of sites in England, Wales, Ireland and the Isle of Man including original fieldwork. The use of an integrative approach will allow the author to consider the material properties and requirements of metal production as well as the social context and the landscape in which the activities took place. Finally this thesis will consider the character of primary copper production in Britain and Ireland not just within a social setting, but also as a fully integrated part of Early Bronze Age life.

1.2. Scope of the Thesis

1.2.1. Geography: Ecton Hill, England and Wales

The Original fieldwork that dominates the body of this thesis was undertaken at the Bronze Age mining site of Ecton Hill in North Staffordshire. The main study area is within the Peak District National Park in Central England. Ecton itself is a limestone hill that has hosted copper mining activity since the Early Bronze Age . It is located between Warslow and Wetton in North Staffordshire, just south west of Hartington.

While the original fieldwork concentrates on Ecton Hill, this thesis draws on evidence from the primary metallurgical *chaîne opératoire* from across Britain. Ecton is presented as a case study for an integrative methodology that widens the focus from a single element of metal production to incorporate a range of evidence for the skilled practices involved. It considers this evidence not as a segregated technology, but as it fits within Early Bronze Age patterns of life.

1.2.2. Chronology: The First Millennium of Metal Production

The most likely date range form mineral exploitation at Ecton Hill during the Early Bronze Age is between 1880 and 1640 according to Bayesian Analysis of the radiocarbon dated recovered from the site. However, this thesis draws on date from first millennium of metal production in Britain from approximately 2500 BC to 1500 BC and incorporates the Early Bronze Age

This is a period for which there is little evidence of permanent settlement. Habitation sites are scarce, very few have been identified or excavated within the main study area (Garner 2001; 2007). Different resources and locales were exploited in a complex pattern of seasonal use and movement across the landscape (Armstrong 1956; Bramwell 1973; Kitchen 2001). Stone clearance and the basis for early field systems can be seen in regions of Britain (Bradley and Hart 1983; Johnston 2001), but monuments and funerary archaeology dominate the archaeology in the landscape (Barnatt and Collis 1996; Hawke-Smith 1981). It is within this setting that this thesis seeks to address the making of copper metal by employing an integrated approach to metal production.

Primary metallurgy is not a process that takes place only within a crucible to be expressed through technological traits, but involves a sequence of interrelated tasks culminating in the smelting of ore. Metallurgy is a skilled practice, or craft, that necessitates engagement with a sequence of interrelated tasks involving a number of materials dispersed across an inhabited landscape. Engaging with space on this scale means turning to landscape archaeology, which has developed a number of means with which to interrogate large spaces and the archaeological traces therein. These are articulated both within theoretical frameworks as well as within practical applications such as the use of GIS software.

1.3. Structure of the Thesis

Given the paucity of existing evidence for primary metal production in Britain and Ireland during the Early Bronze Age this thesis will draw together as many parallel lines of enquiry as possible. This includes a synthesis and discussion of traditional and current approaches to metal work and production. Archaeologists have traditionally approached Bronze Age metallurgy in one of two ways. The first is through typological characterization and the distribution of metalwork, whilst archaeometallurgical analysis has focused on the elemental or isotopic signatures of metals. Both of these avenues of research typically rely on the analysis of deposited (consumed) metalwork and often neglect the evidence for metal production. These approaches are discussed in **Chapter two** alongside the kinds of evidence and interpretation that have been possible in other regions of Europe by participating in field-based research of production.

Metal production is not a simple single-stage process, but is dependant on a chain of interlinking tasks or operations. These include the identification of suitable mineral ores, the successful extraction and consolidation of those ores and finally the reduction of the ore to copper metal. Despite an increase in archaeological data, for mining in particular, the evidence for these stages of the metallurgical *chaîne opératoire* has been poorly integrated into discussions of the Bronze Age. **Chapter three** outlines each of these processes and explores the current archaeological evidence for copper extraction, beneficiation and smelting in Britain. The third chapter will also examine the approaches to the study of metallurgical sites and materials and will highlight methodological concerns and limitations. In response to points raised, an argument will be made advocating an integrated approach to primary metallurgy that considers the current evidence for primary production alongside circulation, use, and consumption within the broader social routines of Early Bronze Age life and emphasises the practices involved as socially and historically informed

Original fieldwork, undertaken as part of this thesis, was conducted on Ecton Hill and within its surrounding landscape. Ecton Hill is located in northern Staffordshire, within the region known as the Peak District. It was the site of a large and rich copper and lead deposit that was exploited through the post-medieval period (Barnatt 2002; Barnatt *et al.* 1997; Porter 2004; Robey and Porter 1972). Material evidence recovered at the site alluded to much earlier mineral exploitation at Ecton hill (Ford 1994; Guilbert 1994a; 1994b; Howarth 1899; Pickin 1999), which was confirmed when an antler tool, recovered from a subterranean context, was radiocarbon dated to the Early Bronze Age (Barnatt and Thomas 1998). In order to engage with both the wider landscape and a complete *chaîne opératoire* as it relates to primary copper production **Chapter four** considers the setting of Ecton, its physical location and the surrounding topography, environment and potential resources existent in its hinterland. The archaeological remains present at Ecton and the surrounding landscape will also be highlighted alongside the historical evidence for mining and metallurgy at Ecton and in the adjacent Manifold Valley.

A major element of this research was the development of an integrated methodological approach, which draws on the concept of materiality as outlined by Gosden (1994) and by Jones (2002; 2004) (see section 1.3.1 below for further elaboration). Rather than dividing social (subjective) and scientific (objective) lines of inquiry, this thesis seeks to integrate the evidence of and for metallurgy with conceptual models of social life in the Early Bronze Age . An integrative methodology should engage with both the social and the material within an appropriate setting. The methodology employed in this thesis, outlined in **Chapter five,** features a nested landscape approach, which engages with landscape modification, and acts of deposition as well as the sites associated with metallurgy. Survey was conducted at various scales, using geophysics, geochemistry, pedestrian survey, and GIS based analysis, aimed at identifying the organization of metallurgical activity within space and the creation of place within a Bronze Age setting.

The results of field investigations are examined in **Chapter six,** leading to a discussion of these results, which will open **Chapter seven**. This penultimate chapter will go on to pull together information from sites related to primary metallurgy across Britain, Ireland and the Isle of Man to consider the context of the making of copper metal on the western fringe of Europe during the Early Bronze Age . The types of mineral exploited, the distribution of mines, and the general absence of expected evidence will all be discussed. Finally, **Chapter eight** will summarize the key points raised in this thesis as well as advocating a change in the way archaeologists and archaeometallurgists address metal production. It will go on to present suggestions for future work, which would increase both our understanding of metallurgical production and its integration into discussions of the British Bronze Age.

1.4. Key Concepts and Definitions

1.4.1. Materiality

The concept of materiality (Gosden 1994) posits that the physical components of the world and the social practices there enacted are mutually re-enforcing (Jones 2002; 2004). Therefore the material world and the social practices re-enforce each other and one cannot be removed without losing the other. The material qualities of objects actively affect their perception, use and symbolism. An approach that considers materiality emphasises how these factors are important and engaged with through social practice. This framework is not without issue, as noted by Ingold (2007). By expanding the concepts expounded by materiality to encompass not just artefacts and landscapes (Gosden 1999), but environment previously overlooked elements, such as air and light, that may impact the interaction between people and place become increasingly relevant.

Materials are not presented to a craftsperson as a tabula rasa, or blank slate, but have their own inherent characteristics with which a skilled practitioner interacts (Ingold 2007). This is as true for the use of wood, clay, stone, metal and a myriad of other materials as it is for place or space although different properties, qualities or characteristics become relevant dependant on the kind of interaction. Using the concept of materiality does not mean a separation of material and mind (c.f. Ingold 2007), but relies on the skills and experience of the craftsperson or agent in the interaction with the material or environment. For example different types of rock have different characteristics, attempting to knap basalt is a frustrating endeavour, but it can be ground and polished into a useful tool. Other materials, such as obsidian will respond differently to the same treatments. A pre-existing knowledge of the material characteristics will affect the interaction of the crafts person with the material.

This is not a return to 'systems' archaeology or a re-imagining of some form of environmental or material determinism, but a recognition that the material world and human societies do not, indeed cannot, exist independent of one another. The material world is shaped by and in turn shapes human behaviour and social interaction (Barrett 1994b; Gosden 1994; Jones 2002). The concept of materiality also embraces the historical context of these interactions where, in essence the intentions of people are translated in to material form, which in turn influences subsequent human action (Jones 2002; 2004)

Materiality does not prioritize context, social or material interpretation, but integrates all aspects of the archaeological record into a meaningful whole. The material qualities of material culture regain importance in the interpretation of how they are used and made meaningful and the social environment in which objects are made and manipulated is incorporated into the understanding of production and use (Jones 2004). Materiality is a concept that introduces the ability of materials to both enable and constrain human activity through social engagement (Gosden 1994). It is a crystallization of the ways people interact with environment and objects and the ways this in turn informs future interactions (Jones 2004).

1.4.2. Chaîne Opératoire

Introduced by Leroi-Gourhan (1993 [1964]) the concept of *chaîne opératoire* was intended to provide a theoretical framework in which technical processes were also conceived as social practices (Conneller 2008). It emphasises the human body as the medium for the transmission of meaning and symbol. Objects were produced through actions that communicated meaning. The concept was readily adopted into lithic discussions where the production of a tool is a reflection of the choices made by the producer with repeated choices representing a tradition that may be shared within a social group (Bar-Yosef *et al.* 1992).

The *chaîne opératoire* is applicable beyond a straightforward reductionist process because it involves the total production process; beginning with the choice and acquisition of the raw material, it follows the biography of the object from its manufacture, through subsequent modification and alteration, to its final use and/or deposition. This network of interrelated actions, people, and environment create the taskscape (Ingold 1993), a concept which has had significant impact on prehistoric archaeology (Conneller 2008; Edmonds 1997).

Engaging with the *chaîne opératoire* allows the archaeologist to follow the choices, material and physical, made during the manufacture and use of an object rather than simply cataloguing it based solely on the end product or mapping the distribution of similar artefacts. By exploring the production of copper metal using the concept of *chaîne opératoire* we can begin to understand more than the technological aspects. By looking beyond the chemical reaction needed to separate copper metal from the minerals in which it is found, we can begin to look at primary copper production as a craft, or a skilled practice that is dependant on the interaction between the producer and materials in a thermo-chemical process. This concept is followed through in chapter three where the existing evidence for Bronze Age metal production in Britain and Ireland is presented within the structure of the *chaîne opératoire*.

2. Archaeological Approaches to Understanding Metal and Metal Production

This chapter examines the background to the study of metals and metallurgy in the archaeological discourse of the Bronze Age in Britain. The current focus of this subject has necessarily been on the objects that have been recovered over successive generations of antiquarian and archaeological investigation. The first part of this chapter examines the trends and methods employed to examine these objects, and the contexts from which they were recovered, and the methods used to try and understand their ultimate provenance. This begins with a brief review of bronze during the Bronze Age in Britain before examining the contextual and analytical paradigms used to understand metal recovered from their depositional contexts.

The second half of the chapter moves from consumption led practices towards an advocacy for the investigation into archaeological traces of production. It begins with an argument in favour of an archaeology of production. This argument is strengthened by the potential disconnect between copper and bronze artefacts and copper and bronze as material. The chapter concludes with a brief overview of production led research in other regions of Europe. This will include both evidence of primary copper production, for comparison later in this thesis, and the kinds of interpretive information available from the field led investigation of contexts of production.

2.1. Part 1: Consumption Led Investigation

Metalwork was once the central focus of Bronze Age studies with Childe (1930) proclaiming that the origins of modern science and industry were descendant from Bronze Age metallurgy. Initially catalogues were filled with typological descriptions of metal work recovered from excavated hoards, round barrows, and other exciting sites (Barber 2003), but as the discipline of archaeology developed so to did the methods it used to interrogate the remains of the past. Following theoretical developments and shifting paradigms, approaches to archaeological metalwork have diverged and developed along tangential lines. Theory led investigation has seen metalwork as a text that, like the archaeological record in general, can be read based on context and distribution to study the ideological, economic and social interactions of Bronze Age communities (Tilley 1991). Archaeometallurgists, on the other hand, have developed analytical tools to investigate the technological processes and material properties of the artefacts that make up the archaeological record (c.f. Bachmann 1982; Charles 1992; Craddock 1989; McKerrell and Tylecote 1972).

Copper and its Alloys in the Bronze Age

The Bronze Age is characterized by the use of initially copper and then bronze as the material from which the main cutting tools, such as axes and knives, were made (Barber 2003: 76). In Britain, this period lasted from roughly 2500 – 700 BC. However, many other objects were also made from copper and its alloys both prior to the full Bronze Age and long into the subsequent Iron Age (Northover 1982a). The earliest metal objects in Britain were made of a weak copper alloy that was also common during the Early Bronze Age in Ireland (1980a; Northover 1980b; 1989). The connection between British and Irish metallurgy in the Early Bronze Age can also be seen in the distribution of a distinctive style of copper axes (1980a; Northover 1980b; 1989; O'Brien 1999). The characteristic metal from which many of the earliest objects were fashioned is a semi-natural arsenical bronze (Northover 1980a; 1989). While at one stage there was some debate over the origin of this metal (Northover 1980a; 1989), recent work at Ross Island, in the South-West of Ireland, has confirmed that this metal was sought after and intentionally produced through the careful selection of an arsenic rich poly-metallic ore known as tennantite (O'Brien 1995; 2004).

Tin, once introduced, is quickly accepted in the British Isles and alloyed with the copper to form a stronger alloy, bronze. From a very early stage, around 2000 – 1750 BC there a remarkably regular ratio of between 10-12% tin to copper can be observed in bronze objects across Britain (McKerrell 1978; Needham *et al.* 1989b;

Northover 1980a). While this level does fluctuate somewhat over the duration of the Bronze Age, in comparison to Europe and the Near East, Britain and Ireland exhibit an unparalleled consistency in tin alloying (Needham et al. 1989: 392).

2.1.1. Subjective Approaches: Contextual Archaeology

2.1.1.1. Deposition: The Consumption of Metalwork

One of the key material characteristics of copper and bronze is its fluidity; the ability to release and recapture the material in new forms (Barber 2003; Bradley 1989). While this property has only recently been made explicit (Bradley 1989), the concept of copper and bronze recycling in prehistory is a tenet of the study of Bronze Age metalwork (Barber 2003; Bradley 1990; Rohl and Needham 1998; Rowlands 1984; Shennan 1982). Copper and its alloys can be repeatedly reshaped or melted and cast into new forms and objects (Rohl and Needham 1998; Tylecote 1987). This property means that even worn out tools can be either rejuvenated, through re-sharpening, or remade by melting and recasting the material thereby posing a reason for tired, damaged or superfluous metalwork to be curated rather than discarded. The retention of copper an bronze may also be inferred from the infrequent recovery of metalwork from settlement or other activity specific sites (Barber 2003; Needham 1989). This implies that the deposition of copper and bronze objects was generally undertaken as an intentional consumption of metalwork (Barber 2003; Bradley 1989).

The intentional nature of the deposition of metalwork is further demonstrated by the contexts from which it is recovered. Metalwork is rarely recovered alongside other evidence for coeval activity (Needham 1989; Wager 2001b), but is frequently found within a fairly narrow range of contexts. The most common division is made between wet and dry contexts (Needham 1989). Wet deposits include those objects recovered from lakes, rivers and bogs and are often seen as irretrievable in contrast to more accessible dry land hoards. Barrett and Needham (1988) argue that there exists a similar distinction between dry hoards, including single finds, and metalwork found in burial contexts; with the latter being ultimately replaced by the deposition of metalwork in wet places. There is also evidence, from accidental loss and the wreak finds at Moor Sand and Langdon Bay, that the assemblage represented in the intentional wet and dry deposits, hoards and votive offerings is not representative of the range of metalwork that was in circulation in the Bronze Age (Barrett and Needham 1988). Whilst the consumption of a restricted range of metal artefacts in specific contexts may represent an ideologically informed practice, the interpretation of the deposits often focuses on underlying social or economic motivations.

Large hoards of metalwork are one type of deposit that has frequently been interpreted as economically motivated consumption. Although these types of material accumulations are better known from the later Bronze Age, hoards have often been understood or interpreted as the consumption of excess material in order to: preserve or increase the over all value of metal still in circulation; the concentration of resources for security, and their subsequent loss; or in advance of recycling or exchange (Barber 2003). These concentrations of bronze are often referred to under familiar headings such as founder's, merchants, or personal hoards, although, again these terms are more commonly applied in the later Bronze Age. These distinctions were originally made in the latter part of the nineteenth century (Evans 1881), but retain remarkable currency in more recent archaeological discussions (Burgess and Coombs 1979). Founder's hoards are those that contain metal waste alongside worn out, broken, and tired implements ready to be melted and recast whilst personal hoards contained treasured objects hidden during turbulent times (Evans 1881). The third category, that of a merchant hoard, contained objects that were complete, possibly freshly cast and in need of final finishing but were in essence ready for use (Evans 1881). Burgess and Coombs (1979) essentially re-iterated the depositional circumstances offered almost a century before: concealment for security; regular storage practices; accidental loss; or votive offerings.

While the terms employed above are typically Late Bronze Age interpretations, Needham (1989) was able to show that the distribution of large deposits, or hoards, changed through time by mapping known find spots. These changed from a focus on the highland regions (and Ireland) in the Early Bronze Age to the lowlands in the Late Bronze Age. He was not able, however, to offer any clarification on the motivation underpinning the consumption of metalwork, other than demonstrating intent through the arrangement of objects in some circumstances (Needham 1989). The purposeful arrangement of bronze objects has been noted in a number of hoard, or associated, deposits (Barber 2003; Needham 1989; Rowlands 1976) and is gaining recognition as ritually motivated.

The deposition of metalwork in funerary contexts is an accepted form of consuming objects in an ideologically or ritually back practice. Objects recovered from burial contexts have traditionally been linked to the individual with whom they are entombed, either as part of their identity in life or as gifts of the mourners. Some funerary objects, such as razors may have been used in dressing or preparing the decedent prior to burial and remain with the body (Barrett 1994b). Needham (1989) was able to demonstrate definitive differences in the types of object found in funerary contexts when compared with broadly contemporary hoards in the Early Bronze Age . However, the recovery of metalwork in funerary contexts is uncommon throughout the Bronze Age (Needham 1989).

Socially motivated deposition often focuses on irretrievable deposits as opposed to founder's or personal hoards. While archaeologists often identify deposits in wet contexts as irretrievable, this does not mean that dry deposits were not also conceptually irretrievable (Bradley 1989). Socially motivated consumption is usually related to ideas of self-aggrandizement, prestige and status that have been seen to underpin the ritual deposition of artefacts including metalwork. The social aspects can be expressed through displays of wealth of excess or, by invoking aspects of reciprocity, inflicting debt on a wider community through deposition (Bradley 1989).

The recent discussions of votive offerings have begun to develop, focused on the discoveries at Flag Fen (Barber 2003; Pryor 2001). Barber (2003) describes the increasingly accepted concept of votive deposits in the context of 'un-associated' finds. These are artefacts that have been consumed though single deposition, frequently, though not exclusively, in wet contexts (Barber 2003). Votive offerings have been an accepted depositional practice in Europe, but because of an underlying ritual motivation, have gained much slower acceptance in Britain and Ireland (Barber 2003; Bradley 1990; Taylor 1993). There is a strong association between the deposition of, in particular, weapons and watery contexts in the later Bronze Age (Bradley 1990). Votive offerings may also be seen as one part of a reciprocal exchange, which need not be limited to interactions between the living members of a community. The consumption of metalwork through votive deposits, as with those in funerary contexts, can be interpreted as the living interacting with a perceived supernatural world. Votive deposits may be seen as attempts to invoke, or given in gratitude for, other worldly intervention.

There are far more complex motivations underpinning the deposition of objects in the Bronze Age than originally understood. The changes in contexts and compositions of recovered metalwork assemblages allude to changes in the social background in which the depositions occurred. The occasional inclusion of metalwork in funerary assemblages in the earlier Bronze Age can be contrasted with an apparent focus on deposition in wet contexts in the later Bronze Age (Barrett and Needham 1988; Needham 1989). The increase in so called founder's hoards in the later Bronze Age, with a general lack of internal or depositional structure, provide a contrast to earlier assemblages, recovered from similar contexts, where the object have been carefully arranged (Barber 2003). Whether or not specific deposits were intended for recovery, the distribution of Bronze Age metalwork across Britain and Ireland is largely the result of the selective and intentional consumption of copper and bronze objects.

2.1.1.2. Exchange: The Circulation of Metalwork

It is the consumed metal objects that dominate the archaeological assemblage connected to metalworking. The visibility of deposited metalwork has led to a focus on the deposition, as discussed above, and the mechanisms of exchange that led to the observed distribution of metalwork in Britain and Ireland. The initial spread of copper objects from Ireland to Britain and the subsequent distribution of metal objects represent networks of exchange that extended beyond the British Isles and into Europe (Bradley 1984). The introduction of tin-bronze across Britain and Europe further demonstrates complex exchange systems, as copper and, to an even greater degree, tin have limited geological distributions (Budd *et al.* 1994; Dayton 1971; Ixer and Budd 1998). The regularity of the tin ratio observed in British bronze objects in particular (McKerrell 1978; Needham *et al.* 1989a; Northover 1980b) alludes to the regular movement and exchange of objects and materials within Britain and Ireland.

The longstanding tradition of typological cataloguing provided a basis to map the distribution of specific metalworking styles and traditions, which in turn allowed conclusions to be drawn about the spread of specific styles or prehistoric metalworking industries and the distance objects had travelled (Ehrenberg 1989). The scale of the distribution of metal objects testified to the existence of exchange networks extending across Britain Ireland and into the European continent. The extent of the circulation metalwork and other materials alluded to the existence of a much larger exchange network that spread across the British Isles, Europe and into the Near East (Kristiansen 1994; 1998; Rowlands 1984; Shennan 1982; Sherratt 1993) The all-encompassing socio-economic theories of Wallerstein (1974) presented a tempting means to address circulation and exchange on a far grander scale under the umbrella of *World Systems Theory*. The idea of a world system, developed for modern economic interaction (Wallerstein 1974), was used to describe the observed and potential core-periphery relationships interlinking distant regions and communities throughout the Bronze Age world (Frank *et al.* 1993; Kohl 1987; Schneider 1977; Sherratt 1993). Proponents of the theory sought to use the concept to describe interconnected webs of exchange observed in the distribution of artefacts made from such materials as copper, tin, lead, obsidian, shell, and amber, which had a limited natural distribution. Whilst one proposal relies on, or perhaps argues for, a pan-European belief system (Kristiansen 1994; 1998), others present the argument that bronze, as a material with unique properties, presented an opportunity for disparate communities with a pantheon of unique beliefs to participate in wide ranging exchange systems (Frank *et al.* 1993; Kohl 1987; Sherratt 1993).

In ever-wider networks of exchange, bronze sat apart from other materials, such as obsidian, amber, and jet, in that its shaping and use was not reductionist. Whereas other raw materials lost value in the creation of artefacts, through the loss of the raw material and/or the projection of a single culturally relevant form, bronze retained the value of raw material through subsequent re-casting. Therefore, the fluidity of bronze enabled ever-wider exchange across different socio-political and ideological systems (Frank *et al.* 1993; Sherratt 1993). Attempts to explain the mechanisms of exchange resulted in a typology of trade, featuring such categories as: direct interaction; down the line; directional exchange; and prestige exchange (Wager 2001b). However a vast pan-European network highlighted the difficulty archaeologists had in articulating systems of exchange, which represented social interactions, without relying on simplified principles of modern economic systems (Barrett 1985; Bradley 1980; 1984; Hodder 1982; Rowlands 1980).

A prestige goods economy was able to describe the perceived inequality in the distribution and consumption of metal objects (Bradley 1984; Needham 1989), particularly as burial accompaniments (Barrett and Needham 1988), but did not recognize other social practices. It also relied on the presence of a stratified society with preferential access to certain materials or goods afforded to an emergent elite. While this introduced an element of social participation into systems of exchange within a community it remained unable to detail the mechanisms of interaction in non-market terms. The solution was found in the discipline of anthropology with the concept of gift-giving (Gosden 1989).

Gift-giving is based on the study on non-industrial societies from several world regions (Gosden 1989) and has had a major impact within anthropology (Godelier 1973; Lévi-Strauss 1969; Mauss 1990 [1925]). Brought into archaeology, the concept of gift giving, or reciprocity, provided a framework for exchange that was able to elucidate the exchange of objects in non-capitalist terms (Bradley and Edmonds 1993; Gosden 1989). Gift-giving is dependent on the acceptance of a gift and suitable reciprocation (Barrett 1989; Mauss 1990 [1925]). This system of balanced, or immediate reciprocity can be contrasted with unbalanced reciprocity where one party is obligated to accept the gift, but is unable to reciprocate and therefore accepts an obligation, or a debt to the giver (Barrett 1989; Mauss 1990 [1925]). Reciprocity can also been applied to the deposition of metalwork with the consumption of copper and bronze in some votive and funerary contexts. Bronze objects found within a burial context could be seen as a continuation of the reciprocal cycle with grave good possibly expressing the fulfilment of a debt owed in life. Similarly, a votive deposit may have been one half of a reciprocal exchange in an attempt to mitigate supernatural influence among the living.

While these interactions function on a local scale and between close communities gift-giving cannot be assumed to function in the same way in large scale, long distance exchange, or between disparate regions within a world system (Barrett 1989; Gregory 1982). The complementary concept of commodity exchange operates on a system of immediate reciprocity where goods or materials are exchanged based on their value to the recipient. Commodity exchange engenders no further obligation, but fosters networks of interaction on a different spatial and temporal scale (Barrett 1989; Bradley and Edmonds 1993; Gregory 1982).

The mechanisms of exchange and deposition form the basis of many of the models of social organization in the Bronze Age and later prehistory in Britain and Europe (c.f. Bradley 1980; 1984; Rowlands 1976; 1980; 1984; Shennan 1982). The concept of reciprocity also provided a means of addressing social interactions, which could include gifts hospitality and labour as well as material goods like metalwork, in cycles of interaction and social reproduction (Barrett 1989). Cycles of gift exchange emphasized the unstable nature of social status (Edmonds 1998) and the competition for status through the infliction of debt by giving gifts and the deposition of objects, including metalwork (Barrett 1989).

2.1.1.3. Context: Metals in Social Organization and Reproduction

It was the theories of Marx (1971 [1857]) and Engles (1969 [1884]) that crystallised the idea of the use and production of metals as indicators of specific developmental stages in human societies (Thornton 2009). Their intellectual successor, V. Gordon Childe, imported these ideas into archaeology where he saw metallurgy as 'proto-science' and a victory of reason over superstition (Childe 1930; 1951; McNairn 1980; Trigger 1986). Childe (1930; 1944; 1957) saw the tasks associated with the production of metals as new forms of labour, which could only be enacted as a result of an improved social organization that allowed portions of the labour force to be removed from traditional subsistence activities. Therefore, the traces of metallurgical production, including: slag; crucibles; mould fragments; and metalwork itself, are indirect evidence for the specialization of labour and social stratification in Bronze Age societies (Childe 1957; Childe 1962).

Metallurgy was, according to Childe (1947; 1962), a skill practiced by itinerant specialists that maintained a position on the edge of social, political and economic organization. By maintaining an itinerant lifestyle, without specific allegiances to existing agricultural or pastoral communities, the metallurgical specialists were able to remain innovative and explore the potential of their new medium (Childe 1947; 1962). This in effect marginalized the metallurgist and an active agent, but emphasized the importance of metal and its production within social interactions and reproduction. Childe's intent was to isolate the work of the metallurgist, as one of many productive practices, as the focus of archaeological inquiry (Trigger 1986). His belief was that culture was unknowable without internal knowledge, what Bourdieu (1977) called *habitus*, but that production was based in technology, a repeatable and knowable aspect of human development (Childe 1944; 1957; McNairn 1980).

The idea that mining and metallurgy represented new forms of labour is pervasive throughout British and European archaeology as are the themes of labour re-organization and control of production interlinking metallurgy and social change (Branigan 1968; Childe 1957; Krause 2009; Rowlands 1971; Sherratt 1984).

However, with archaeologists increasingly seeking to address questions of social interaction and reproduction, focus moved from ideas of production, which had been separated from the wider social construct (Childe 1944; 1957), to exchange and deposition (Bradley 1989). Sherratt (1976; 1984) demonstrated that a focus on production led social change was over reliant on the role of metals and that metalwork was not the only material in circulation during the Bronze Age. Widespread exchange was neither limited to the Bronze Age, nor dependent on copper and bronze. A range of exotic materials was circulated along networks that had existed in the later Neolithic (Sherratt 1976; 1982; 1984). Rowlands (1980; 1984) explored the impact of production, circulation and ultimately the consumption of a range of material on Bronze Age socio-political reproduction. The system proposed by Rowlands relied on differing cycles of exchange, including a prestige goods exchange, which was used to maintain social positions and political status (Rowlands 1980; 1984).

With a focus on exchange and deposition, the concepts of gift-giving and reciprocity had a significant impact on theories of Bronze Age social interaction and organization with new ideas on the development of social ranking and the emergence of hierarchy and the re-organization of labour (Bradley 1984; 1990; Bradley and Edmonds 1993; Gosden 1989). Reciprocal exchange and competitive deposition emphasized the unstable and changeable nature of social relations in the Bronze Age and the role of metalwork in social and political reproduction (Barrett and Needham 1988; Edmonds 1998).

The distribution and consumption of copper and bronze continue to have a central role in the conceptualization of Bronze Age ritual practice, exchange and social organization. Ideological changes are expressed through the changing context and content of the consumption of copper and bronze. Changes in social organization are seen as intrinsic to the development or adoption of new strategies for material acquisition and production methods. Control over the exchange of specific objects or materials, exemplified in a prestige goods economy, are dependent on a stratified society with specific sects or individuals able to exert greater influence within communities and engage in exchange with similarly positioned people in other communities. Changes in social identity are expressed through symbols of status such as objects of bronze recovered from funerary contexts and other contexts of consumption.

2.1.2. Objective Approaches: Science Led Archaeology

Archaeometallurgy emerged in the 1960's and 70's, couched in the paradigm of the 'New Archaeology' and defined as "the study of ancient metallurgical technology, focusing exclusively on the manufacturing process from ore selection and mining to the production of metal objects" (Thornton 2009: 26). It grew on the initial success seen in analytical methods and the desire expressed by Clarke's paper *The Loss of Innocence* (1973) for a more science-oriented discipline. Archaeometallurgists laid claim to the investigation of metal production and fieldwork on metallurgical sites went into decline. Field archaeology, relieved of the study of metal production by the emergent prestige discipline, focused on domestic and ritual sites whilst archaeometallurgical focus turned to laboratory analysis and, as laboratory practice came to dominate, fieldwork faded until virtually no fieldwork investigated the contexts of production.

The seceding of the study of archaeological metals and their production began with attempts to provenance the metal within artefacts to a specific ore source. Based originally on Cann and Renfrew's (1964) work on obsidian sourcing, provenance studies used elemental signatures, the trace elements within both object and ore, to identify a relationship between copper objects and ore bodies from which the metal was derived. The method reflected the desire for more scientific inquiry within the discipline. Early concern was voiced over the applicability of a technique developed for a *reductionist* process in lithic production to a vastly different, *transformative* process in metal production (Butler and Van der Waals 1964). The major concern was that trace elements within a source, while remaining unaltered through the impact needed to remove a flake, could not be expected to behave in the same way when subjected to extreme heat intended to transform one material into something else (Budd *et al.* 1996; Butler and Van der Waals 1964), Cycles of melting and alloying further complicate the idea of tracing an elemental signature to a single source (Tylecote *et al.* 1977). However, initial provenance studies began to show results in the Aegean (Renfrew 1969) and a new methodologies arose based on lead isotopes. Lead Isotope analysis measures the different ratios of lead isotopes within a sample in order to again connect it with an ore body (Stos-Gale 1989). The new technique initially found success on lead and silver (Gale and Stos-Gale 1981; Stos-Gale 1985) and ultimately on copper alloys (Gale and Stos-Gale 1989; Rohl 1995).

The fetishization of the study of archaeological metals and their production was completed with its removal from mainstream archaeology and the establishing of archaeometallurgy as a prestige sub-discipline (Doonan and Day 2007: 3; Pfaffenberger 1988: 241). Cutting edge scientific techniques were applied to the study of metals whist drawing on principles from metallurgy, materials science, geology, chemistry and physics, all of which reflected the desire to re-package archaeology on a more scientific footing.

Archaeometallurgy, like the objectivist approach from which it was borne, is based on the underlying principle that the material properties of metalwork and the associated debris are the final result of knowable, predictable, and eminently repeatable processes (Jones 2002; Pfaffenberger 1992). For example, the steps taken by the ancient smith are believed to be encoded in the resultant materials and objects (Craddock 1995; Northover 1989); however in the absence of the production debris, archaeometallurgical research in Britain has turned to the end products, the finished objects, in an attempt to recover the conditions of the initial manufacture of the material from which the object is made.

There are three broad methods that archaeometallurgical specialists have used in attempts to recover traces of primary production from completed objects that have been recovered from contexts of consumption. These analytical methods are broadly based in the typological tradition and include: elemental composition [or chemical impurity] (Cooghlan and Case 1957; Needham *et al.* 1989a; 1980a; Northover 1980b; 1989); lead isotope signatures (Gale and Stos-Gale 1989; Rohl 1995; Stos-Gale 1989); and Imp-LI (Rohl and Needham 1998), which is a combination of the two. These methods are used to produce groups or metal types, which can be used to further develop distribution maps based on the type of metal held within specific artefacts. These methods are used essentially in an attempt to provenance the metal, to tie it to an ore body and thus locate its source.

2.1.2.1. Trace Element Analysis Trace Element Analysis

As mentioned above, trace element analysis originated as a technique for identifying the provenance of obsidian, thereby revealing information on the movement of material in prehistory (Cann and Renfrew 1964). It was imported to the study of early metals with the same goal in mind (Renfrew 1969). By employing techniques such as electron probe analysis (Northover 1980b; Northover 1982a), optical spectroscopy (Northover 1982a), and atomic absorption spectrophotometry or AAS (Needham *et al.* 1989a; Northover 1980a) to identify an elemental signature within a metal artefact, archaeometallurgists hoped to be able to source the material within that artefact to a known ore body or region (Budd *et al.* 1996; Needham *et al.* 1989a; 1980a; Northover 1980b; Wayman 1991). However, there are complex relationships between the ores, the production processes and the metals that can affect the final composition of objects (Tylecote *et al.* 1977).

The potential differences begin within the ore body itself. Few ore bodies are homogeneous with variation in trace elements and chemical compositions through the same mineral deposit which may not be reflected in a completed object (Wayman 1991). Any correlation can therefore be complicated by an inadequate sampling of the source material and/or object (Budd *et al.* 1996; Wayman 1991). The continued exploitation of mineral sources both in the Bronze Age and in the intervening centuries creates a potential sampling bias as it may no longer be possible to sample the same part of an ore body that was used in prehistoric fabrication (Wayman 1991).

Aspects of the beneficiation and the smelting processes can also influence the elemental signature (Budd *et al.* 1996; Wayman 1991). Ores are exposed to a variety of potential external influences during the transformation from ore to metal. Beneficiation itself is designed to alter the elemental makeup of the ore, in order to increase the final volume of metal produced, by removing impurities prior to smelting (Craddock 1989). This process could therefore alter the elemental signature of the metal produced (Wayman 1991). The smelting process involves a mix of fuel, ore, clays, in the form of crucible or furnace, and possibly a flux to aid the separation of copper from other elements (Craddock 1995). The use of a flux in particular increases the probability of altering the elemental composition of the metal produced through the addition of elements, and in particular iron, present in the flux material (Craddock 1989; Northover 1980a).

Finally the potential for mixing metal from different sources, either in alloying or in the recycling of scrap, introduces additional sources of biasing the results. In the British Bronze Age, alloys of copper and tin are well known. It is also known that lead was at times added to the bronze. As seen at Ross Island (insert O'Brien Ref) there is potential for identifying metal sources and establishing provenance for the copper based on the elemental signature; however, the practice of mixing copper metals, and other metals, from distinct sources cannot be ignored. This has not deterred specialists from trying to produce real results by employing trace elemental analysis in the identification of metal typologies, or metal groups, and in provenance studies.

Different authors have identified a range of largely overlapping elements that were present in the majority of metal objects and that they believed to have been inherited from the parent ores. Northover (1980b), in an analysis of approximately 550 copper and bronze objects from Wales, identified the impurities of primary importance as arsenic (As), antimony (Sb), nickel (Ni), cobalt (Co) and silver (Ag). Using the presence or absence and the relative ratios of these minerals within the bronze metal, he identified a number of metal types. Northover also identified both lead (Pb) and iron (Fe) within several metal objects, but did not include these elements in his interpretation of metal groups because of the high probability that they were introduced into the metal mixture either during the smelting process as flux, in the case of iron or, in the purposeful creation of an alloy, in the case of lead.

Tin (Sn) is also present in the majority of objects but again cannot be used to identify an ore source as it is certainly added later in the creation of bronze.

Early Bronze Age			Middle Bronze Age		Late Bronze Age	
Type		Impurities	Type	Impurities	Type	Impurities
A			M1	As=0.65-1.05%	S	As>0.40-0.50%
		As, Sb, Ag Sb>0.46%		Ni=0.20-0.45%		Sb>0.40-0.50%
				Co = 0.05%		Ni - 0.25%
	A1	As > Sb > Ag		Sb - Trace		Ag - 0.25%
	A1*	alloyed with As				
	A2	As < Sb > Ag	M2	As >1.05%	S1	As:Sb = 1:1
	A3	As ~ Sb ~ Ag		Ni=0.20-0.45%	S2	As:Sb = 1:2
	A3*	alloyed with As		Co = 0.05%		
	A3a	all under .10%		Sb - Trace	T	As < 0.40%
						Sb < 0.40&
B			N1	As=0.35-0.70%		Ni < 0.40%
		As, Ni		Ni=0.25-0.50%		Ag < 0.40%
				Co = 0.05%		
	B1	As>0.75%, Ni>0.06%		Sb=0.05-0.15%	T3	Considerably Purer
	B1*	As>1.25%, Ni>0.06%				As < 0.20%
	B3	As<0.75%, Ni>0.06%	N2	As=0.35-0.70%		Sb < 0.20%
	B4	As<0.25%, Ni<0.06%		Ni > 0.50		
				Co = 0.05%		
C		Trace impurities only		Sb=0.05-0.15%		
D		As, Sb, Ni, Ag	O	As=0.50-1.25%		
				Ni < 0.20%		
E		As, Sb, Ni		Sb=0.10-0.20%		
				Ag=0.10-0.20%		
F		As, Ag				
	F1	As > Ag	P	As=0.10-0.40%		
	F2	As ~ Ag		Ni=0.10-0.30%	As	Arsenic
	F3	As < Ag		Co=0.05-0.10%	Ag	Silver
				Sb - Trace	Co	Cobalt
G		Ni			Ni	Nickel
			R	Ni	Sb	Antimony

Table 2. 1 Bronze Age Metal Types (after Northover 1980a)

Northover (1980a) also acknowledged the possibility that copper was intentionally alloyed with arsenic in the earliest phase of metal use in Britain. At the time of his investigation, he assumed that the arsenic would be drawn from the same poly-metallic source as the copper and thus, other than the obvious increase in arsenic content, would not significantly alter the ratio of the other impurities within the resulting metal (Northover 1980a). With the excavation of Ross Island, in Southwest Ireland (O'Brien 1995; O'Brien 2004), this has proven to be the case.

As the goal was to establish the provenance for the metal exploited at various times by early metal smiths and, in particular, to test the hypothesis that different sources were in use during the pre-eminence of different metal traditions, it was also important to propose sources for the ore. In this way the modern typological divisions of metal artefacts and their implications of different archaeological cultures might be strengthened. This goal, however, was only ever partially met. Initially only broad generalizations could be made about ore sources because actual mining sites dating to this period were unknown. Samples of ore were not tested under the original programs and claims regarding potential source areas were not well substantiated.

Based on the creation of metal groupings (discussed in greater detail below) and assumed sources, Northover (1982a) proposed a model of Bronze Age industrial production and exchange. The model was very general and prioritized the suspected continental contributions over the potential indigenous development of metal sources and trade networks. This model also conformed to the idea of the Wessex and Thames Valley core region and explored the technological development in these regions at the expense of the metalliferous zones further to the west.

In a subsequent study, Ixer and Budd (1998) were able to refute most of the claimed sources through a program of sampling and analysis performed on the ores from both known and suspected Bronze Age mineral sources. They discovered that the majority of metal sources in Britain would have produced a nearly pure copper (Ixer and Budd 1998). The discovery of copper mines in Britain, and in Ireland, dating to the Bronze Age, and the analysis of copper ores from those sources, has undermined the many of the suggested sourcing proposed by Northover (1980a; 1989) and the model of organization and exchange that was inherently biased towards the south east of England. That said a few of the metal types identified by Northover (1980a) can be sourced to specific locations, such as metal type A, which is a product of the fahlore tennantite exploited at Ross Island. Based on the arsenic content, metal type F may also come from this same source.

A study conducted along similar lines by Needham et al. (1989a) used AAS to define elemental compositions. This study used arsenic (As), antimony (Sb), silver (Ag), nickel (Ni), cobalt (Co) and zinc (Zn), the elements that were employed by Northover, but also included bismuth (Bi and lead (Pb) in defining its metal groups (Needham *et al.* 1989a). Iron (Fe) was not included on the same grounds as the studies by Northover. The study by Needham et al. (1989a), however, was also unable to define provenance for the metal groups and concluded that such an endeavour was beyond the scope of elemental analysis. They further contended that the basic premise behind provenance studies rested upon unsubstantiated and more likely invalid assumptions (Needham *et al.* 1989a). The authors did, however, hope to re-task trace element analysis, employing it in new and more constructive ways

2.1.2.2. Lead Isotope Analysis

Lead Isotope Analysis is another form of laboratory analysis that has again been employed specifically to identify the source of the metals used in the Bronze Age. It is a technique that was originally intended to date geological deposits and has been employed in geology to study the formation of ores and in geological prospecting (Rohl and Needham 1998). Natural lead consists of four isotopes, which are known by their atomic mass. Lead 204 is the only one that is not radiogenic in origin while the other three, lead 206, lead 207 and lead 208 all derive from the radio active decay of uranium and thorium (Rohl and Needham 1998; Stos-Gale 1989). This technique measures ratios of the four lead isotopes in relation to each other to establish a lead isotope signature that can then be matched to other objects and to ore sources (Stos-Gale 1989).

Lead Isotope ratios, unlike elemental composition, will not fluctuate within an ore body (Stos-Gale 1989). However, there may be, on occasion, examples of single vein ore formations that have returned variable lead isotope compositions due to radiogenic decay (Stos-Gale 1989: 276). Isotopic signatures will also remain uniform throughout a variety of minerals within the same ore deposit. Thus if there are sulphide ores underlying oxide ores, or galena in the same ore formation as a copper ore, all these ores, and the resulting metals, will retain the same lead isotope signature (Stos-Gale 1989).

The isotopic ratios will also remain the same throughout the process of beneficiation, if applied, and the pyrotechnic processes of smelting or re-melting (Rohl 1995; Rohl and Needham 1998; Stos-Gale 1989). Thus a measure of copper will retain the same lead isotope signature through countless episodes of reuse and recycling as long as it is not mixed with metal from other sources (Rohl and Needham 1998; Stos-Gale 1989). Corrosion should also be viewed with some caution because, in copper objects with a low lead content, corrosion introduces the possibility that 'the true lead isotope composition' of an artefact may be altered through the contact with a different isotope ratio within the burial environment (Stos-Gale 1989: 275). Similarly, objects that have had lead introduced into the metal, as an alloying material, are also problematic. In these cases the lead isotope signature will be that of the introduced lead, that is likely to be from a different source, rather then for the copper (Rohl and Needham 1998).

2.1.2.3. Imp-LI Analysis

The final method of laboratory led analysis that has been employed in the quest for provenance in Britain is that of a combination of trace element analysis, or elemental impurity, and lead isotope (Imp-LI). The Imp-LI program was a project undertaken by Brenda Rohl and Stuart Needham, published in 1998, which undertook the analysis of bronze objects from the British Museum (Rohl and Needham 1998). The analysis consisted of trace element analysis, using electron probe microanalysis, combined with lead isotope analysis (Rohl and Needham 1998). From these analyses the authors defined twenty-three distinct groups, which they called Imp-LI groups (Rohl and Needham 1998). This approach limited the potential complications of each of the individual analyses by providing two sources of data relating to the possible provenance of the metal. Where this project differed significantly from other laboratory based analyses is that it applied the same combination of chemical analysis and lead isotope analytical techniques to copper and lead ore deposits, both from the mines that now have a presence in the archaeological record and from other known ore bodies (Rohl and Needham 1998). The Imp-LI groups could then be compared to the Imp-LI signatures of the copper deposits in an attempt to source the material.

Imp-LI group	Copper	Brithdir	Mile Cross	Willerby	Arreton	Acton	Taunton	Penard	Wilburton	Ewart	Llyn Fawr
1	15(2)	6									
2	5										
3		4									
4		4		1							
5			2								
6		cf2		8							
7					6		cf1				
8					16(2)						
9						9					
10						7					
11						5(2)					
12							9				
13							20(6)				
14								55	0(1)		
15								10	1		
16									29(1)		
17									7		
18									6(1)		
19										4	
20										3(1)	1
21										4	1
22										66(9)	1
23											8
Ungrouped	2	1	3	0	7	0	7	6	0	6	0
No Chemical Analysis	3	0	0	0	0	0	8	2	7	4	0
Total	27	17	5	9	31	23	51	73	53	97	11

Table 2. 2 Imp-LI groupings (after Rohl and Needham 1998)

What the authors discovered in the course of this project was that direct object – source correlations were rare (Rohl and Needham 1998). Frequently, the metal contained within a given artefact showed not one source, but a mixture of potential parent material based on the difference between lead isotope and elemental impurities (Rohl and Needham 1998). This study highlighted the practice of mixing metals from different sources, as those sources were exploited in prehistory and the problem of multi-provenance objects. This means that rather than attempting to identify single source origins for objects it may be possible to identify contributions from sources to the overall temporal and/or regional metal pool, which can now be referred to by Imp-LI group (Rohl and Needham 1998). By tracing changes in the metal pool and the varying inputs from a variety of known sources it will be possible to observe shifts within industries in the Bronze Age and identify periods of gradual shift versus wholesale change in the contributions to the available metal (Rohl and Needham 1998).

2.1.2.4. Summary of Archaeometallurgical Techniques

A surprising correlation was observed between specific metal groups or types, as identified through trace element, lead isotopes or the combination of analyses, and existing typological divisions (Northover 1980a; 1989; Rohl and Needham 1998). These are not along divisions of form, informing function, but observed industries based in style. This in effect produces yet another means of cataloguing metal artefacts and defining metalworking industries. These analyses, have also been used to establish the provenance of specific metal groups, for example the metal types identified by Northover (1980a; 1989) A and F, which have a strong correlation to Ross Island; and possibly B, which appears to have connections to continental sources. Once the alloying and mixing of metals and ores become more common the groupings relate less to any specific ore deposit or mineral origin. Neither are they able to illuminate any part of the primary production of copper metal.

With the exception of the fahlerz ore from Ross Island (O'Brien 2004), no known Bronze Age copper mine produces a characteristic elemental signature. Efforts to identify a connection between object and ore using lead isotope analysis have provided only tenuous possibilities based on faintly radiogenic lead isotopes found in part of the ore deposits on the Great Orme (Rohl and Needham 1998). The testing and characterization of ores from known Bronze Age mines using the combined Imp-Li method has shown that different sources may have contributed to an available pool of metal, circulated in cast objects, at various times, but that any specific connection between any of the identified sources and metal objects is unlikely due to the frequent and regular mixing of available metal (Rohl and Needham 1998). This practice was so regular that no one source appears to dominate the pool at any given time, only contribute to the metal in circulation (Rohl and Needham 1998).

2.1.3. Problems with Consumption Led Inquiry

Metals and metalworking have been central in the development of archaeological models of the Bronze Age since Childe (1930; 1951) highlighted their role in the development of social stratification and the re-organization of labour. The work of Childe continues to have a lasting impact in archaeological interpretation (c.f. Maddin 1988; Shennan 1982; Sherratt 1976; Trigger 1986; Tylecote 1987; Yener 2000). However, despite an overemphasis on the visible metal assemblage of the Bronze Age (Sherratt 1984), the presence of copper and bronze does not inherently represent a significant change in social organization (contra Childe 1930; Rowlands 1980). Rather the significant changes that were assumed to coincide with the adoption of metallurgy in Britain and Ireland appear to have developed over the course of the Bronze Age (Rowlands 1980; 1984). Among the most obvious changes visible in the archaeological record are those that distinguish the earlier from the later Bronze Age. These are seen most notably in the changes in land use and settlement, but are also reflected in funerary traditions and craft industries (Brück 2000; Fokkens 1997; Mullin 2003).

Bronze Age specialists have tended to see metalwork as the herald of new tasks, unique from anything seen before; however, as will become apparent in the following chapter archaeological evidence from productive activities the Late Neolithic and Early Bronze Age express many similarities (Barrett and Needham 1988; Edmonds 1995; Sherratt 1984). Casting can be seen as a new method of producing an object, though it relies on ceramic and lithic knowledge in the manufacture of moulds (Tylecote 1986; 1987). The purportedly new activities of mining and processing the ore exist within the lithic traditions of the preceding period and parallels can be seen in the *chaîne opératoire* of stone axe production (Bradley and Edmonds 1993; Edmonds 1990; 1995) or the or the winnowing and grinding of grain (Giles 2007; Hingley 1997). Alloying metals can be seen as a new skill, though not entirely removed from ceramic production where the mixing of clay and temper is understood to strengthen the overall material (Doonan and Day 2007; Rice 1987; Sinopoli 1991) or food production where ingredients are mixed to into new forms (Giles 2007).

While Sherratt (1976; 1982; 1984) highlighted the over emphasis archaeologists placed on metals based on their archaeological visibility, they remain one of the primary forms of empirical evidence on which archaeological models are based (Barrett 1989). The premise that underlies the models of social organization and reproduction is that differences in the distribution and consumption of certain objects represents differential access to materials or control over production (Edmonds 1998). There has been little attempt to explain how the distribution of these deposits as the product of conscious exchange and consumption can also be directly representative of production (Wager 2001b).

The concepts of reciprocity and layered exchange systems, based on social status or political power emphasize the role of production and exchange in social reproduction (Barrett 1989). However, there is a danger in producing characterizations based on the evidence provided by distribution rather than further interpretation (Bradley and Edmonds 1993). General models of Bronze Age social organization (e.g. Rowlands 1980) have been developed in order to provide 'best fit' explanations the evidence from disparate social systems throughout Bronze Age Europe based on an objectivist idea of universal human practice (Wager 2001b). Such models are incapable of addressing individual social interactions represented by specific events because they have been abstracted from the empirical evidence to form general principles (Barrett 1994b; Bradley and Edmonds 1993). This results in the loss of regional specific and historically contingent identities that are involved in production, exchange and social reproduction.

The Bronze Age was not a homogeneous period with variation in funerary traditions, settlement patterns and production visible across both temporal and geographical dimensions. Individual periods identified as the early, middle and Late Bronze Age can be further subdivided based on prominent typologies of either metalwork (c.f. Barber 2003; Northover 1980b; 1989) or ceramics (c.f. Barrett 1980; Longworth 1984), but these are modern divisions and are unlikely to reflect actual distinctions made by Bronze Age peoples.

Approx. Date	Metal Typology	Other Material Culture
Early Bronze Age		
2500-2150	pre-tin Bronze / copper	Beaker
2150-2000	Brithdir	Late Beaker
2000-1900	Mile Cross	Early Urns
1900-1700	Willerby	Wessex 1
1700-1500	Arreton	Wessex 2
Middle Bronze Age		
1500-1400	Acton Park	Deverel-Rimbury
1400-1275	Taunton	
1275-1140	Penard	
Late Bronze Age		
1140-1020	Wilburton	High Lead Bronze
1020-800	Ewart	
800-650	Llyn Fawr	Use of Iron

Table 2. 3 Bronze Age metalwork typologies (after Mullin 2003; Northover 1980a; 1982a)

As highlighted above, the deposition of metalwork was largely intentional and selective (Barber 2001). These premeditated deposits adhere to socially informed prohibitions on what may be consumed and where deposition may take place; therefore recovered objects may not represent the metalwork in circulation

(Barrett and Needham 1988). Different kinds of artefact may have been involved in different levels or systems of exchange and specific objects may have been collected or curated for future consumption whilst others readily exchanged and/or recycled. The apparent systemic demand for increasing metalwork and raw materials to feed competitive exchange and consumption mirrors modern economic intensification (Barrett 1989; Barrett and Needham 1988) and assumes a continuous and increasing supply to meet demand.

The paucity of production evidence in Britain and Ireland has meant the technological studies have relied on chemical and isotopic analyses of completed artefact in attempts to understand the production process. However, consumption led investigation can only explore the lifecycle of the final object; it cannot penetrate repeated mixing, alloying and casting processes to identify previous iterations in which the metal was used. The techniques described above have been employed elsewhere in the identification of technical processes and ore sources based on the analysis of abandoned production waste (c.f. Bassiakos and Philaniotou 2007; Chernych 1992; Müller and Pernicka 2009). However the dearth of this material in Britain and Ireland has severely limited the ability to approach cycles of production. This has left the focus on deposition and exchange with an overall impression that metal production in Britain and Ireland functioned solely in response to a demand for raw materials and metalwork on the margins of exchange and consumption. This kind of model is reminiscent of the 'Itinerant Smith' (Childe 1930; McNairn 1980) in a new guise where metal production is a mechanistic operation on the periphery of the societies that it benefits.

2.1.4. Moving Forward: Evidence of a Paradigm Shift

Goodway (1991) described archaeometallurgy as moving from a specialization that focused only on metal to one that examined materials and had become a more integral aspect of archaeology and the study of material culture. Rather than standing in isolation, archaeometallurgy should be about augmenting archaeological understanding "…of the rise of craft specialization, the organization and importance of pre-historic industries, the effects of new technologies on societies, the extents and limits of cultural contact and the impetus and alterations required to change rudiments of social infrastructure …" using empirical analysis and scientific methods (Ehrenreich 1991: 55).

The principle behind this kind of archaeometallurgical analysis is that the social reason for the manufacture of an object is related to the qualities of the object and therefore the goal should be observable from the product (Smith 1981). Thornton (2009) uses the analogy of the making of a knife. If the maker wanted to create a stronger blade then that should be evident from the choices taken during its manufacture. If however, the goal was not to produce a cutting blade, then that too should be visible in the steps of its manufacture. Inference as to the potential use of the object can then be made based on the techniques employed in its manufacture, a strong blade alludes to a desire to use the knife for cutting where as a weak blade may be destined for display or consumption. (Thornton 2009: 28-29).

This type of analysis has been employed to great effect in Europe. Kienlin and Stöllner (2009) present a wealth of data on initial production and post-production modification that can be gleaned through metallurgical analysis of copper and copper alloy objects. The kinds of data include, but are not limited to: the mechanical properties of the material and/or finished object, casting methods and positions and the practices of cold working (Kienlin and Stöllner 2009: 78). They are also able to infer the working knowledge the metal smiths had of the material they were using through the processes enacted upon it, or not, after it was cast.

Both Smith (1970; 1977; 1981) and Lechtman (1979; 1984; 1996; 1999), whose ideas of metallurgy and craft [technology] built on the idea of 'Habitus' (Bourdieu 1977), believed that the archaeometallurgist should, with enough data, be able to deduce local craft traditions thus better understand the choices made by the practitioner. Through understanding the choices made in the production of objects the specialist can then begin to understand the goals of manufacture and the taboos and society that structured ancient practice (Thornton 2009). The approach promoted by Smith and Lechtman, though popular in the United States, has gained slower acceptance among British archaeometallurgists. More recently the concepts applied by Lechtman have begun to spark discussion in wider audiences on the social organization of craft and production and the impact of material properties on their use (c.f. Dobres 2000; Ingold 2007; Jones 2002; 2004; Pfaffenberger 1988; 1992).

2.2. Part 2: Towards a Focus on Production

Copper and it alloys are the only material in prehistory that is truly transformative and yet appears in the archaeological record. Its production and use is dependent on different stages of manipulation, from smelting to casting to annealing to sharpening, which each leave evidence in the material record. By engaging with the evidence of production, archaeology can avoid a dependency on the recovered objects and begin to develop a layered approach to a unique material.

2.2.1. Object versus Material: Primary and Secondary Production

The normal lifecycle of an artefact begins with its production and ends with its consumption and deposition (Bradley 1990); however, copper and its alloys are materials that can be recycled (Bradley 1988; Needham 1989) and, therefore, re-used through numerous 'artefact lifecycles'. The material and object lifecycles run parallel in shared but different cycles. The lifecycle of a new artefact begins with the end of the old artefact, its destruction, but the material is neither produced nor consumed in this sequence. This is because there are two distinct phases involved in metal production, two separate, but interlinked chains of operation. The first phase is primary production and involves the mining, processing, and smelting of the mineral ores to produce raw metal whilst the second phase involves the melting, alloying, and casting of the metal into an object and its subsequent use.

These are not necessarily mutually exclusive activities nor do they necessarily occur in discreet locations; however, primary production is necessary only in the initial making of the metal, whereas secondary production can be enacted repeatedly using the same material again and again (Barrett and Needham 1988;

Needham 1989). Primary production is the making of the material whilst secondary production is the making of the object. New artefacts can be made and remade from existing metal locked within any object (Barrett and Needham 1988). The end of this cycle comes with the deposition of the artefact, which consumes both the object and the material within (Barrett and Needham 1988; Bradley 1989; Needham 1989).

Consumption led enquiry frequently overlooks the parallel aspects of object and material that are inherent in all Bronze Age metalwork. These different aspects of bronze each have their own value; the value of the object is culturally contingent (Kristiansen 1989; 1994) whist the value of the material is assumed to be inherent in its nature. Research that is led by artefacts recovered from contexts of consumption is focused on the conditions of the **objects** production, use, and ultimate deposition (Ehrenreich 1991). It is not possible to examine the contexts of primary metallurgy, the making of the metal itself, from object-oriented research. Considerations of the material are limited to the information it may provide regarding the intended or actual use of the artefact prior to its consumption (c.f. Ehrenreich 1991; Goodway 1991; Müller and Pernicka 2009; Needham *et al.* 1989a; Northover 1982b).

The assumption that social value is limited to the object justifies a split focus with the object taking precedence in most social engagement, and the material holding focus within wider dialogues of economic interaction. However, based in systems of reciprocity across wider spheres of socio-economic interaction, if the gift of an object is only valuable because of the metal from which it is made (Sherratt 1976; 1993), then is the gift not the material rather than the object? If the gift is given and accepted based on the material regardless of its form and with the understanding that the object may be reduced and recast into more culturally relevant forms within the new community (Sherratt 1993) then it may be the material itself, rather than the object that represents the social relationship between the participants. It is not necessarily the case that one value was ignored in the face of the other or that social significance was limited to the object.

2.2.2. The Importance of Primary Production

Despite parallels with other acts of production, primary copper metallurgy is an interesting and unique process that transforms rock into a malleable and useful material though high temperature pyrotechnics. It is a visually impressive process resulting in copper metal and, at many sites across Europe, slag. The continued absence of the latter in the archaeological record of Britain highlights the difference between Britain and other areas of Europe, where the understanding of production is more closely tied to evidence of production.

With recent developments in Early Bronze Age copper mining (c.f. Gale 1989; Jackson 1968; James 1988; Lewis 1990b; O'Brien 1994; 2004; Timberlake 2003b; Timberlake and Jenkins 2001), it is time to address the contexts of primary production. Proposals for the approach to copper smelting, based on the absence of evidence (Craddock 1990b; 1995; Craddock and Craddock 1996; Craddock and Meeks 1987; Pollard *et al.* 1990; Timberlake and Prag 2005) have not adequately accounted for the mining evidence that is now available. Conversely, the development of models of social change and social organization presented above (Bradley 1980; 1984; Rowlands 1976; 1980; Shennan 1982; Sherratt 1984) have been applied in Britain on the expectation that the evidence for metallurgical production, yet to be recovered in British contexts, would broadly match the evidence already recovered in other parts of Europe.

An approach that examines the biography of the material, beginning with its production, is essential to understand the role of metal and metalworking in social interactions (Doonan and Day 2007). The assumption that a mechanistic productive cycle existed on the periphery of society feeding re-organization and social ranking based on the consumption of metal artefacts is no longer tenable. Likewise discussions of British and Irish metal production based on allegory, ethnography and consumption do not add to the understanding of metallurgic practices and their role in the creation of identity and social reproduction. Models of production and its role in social re-production based on European data provide a useful comparison, but cannot be blindly imported to British and Irish contexts without sufficient evidence, as they may not reflect indigenous practice.

2.2.3. Examining Production: Approaches to Primary Production from other Regions of Europe

It is only through a detailed examination of production, the materials and the context, that archaeologists can approach the practises involved and the role of metalwork in the creation of identity can be understood. The models discussed in this section are based on the evidence of Early Bronze Age metal production from diverse regions of Europe. This is not intended to be a comprehensive review of Early Bronze Age evidence, but a synthesis of primary copper production in the alpine, Aegean and Iberian regions that highlights the kinds of evidence and key interpretive fragments that have been recovered through a focus on production beginning with fieldwork.

2.2.3.1. The Alpine Region

Bronze Age metallurgical production, and primary copper production is already very well known in the Alpine region of Central Europe. The extensive fieldwork that has taken place in this region is well published elsewhere (Della Casa 2003; Doonan 1999; Kienlin and Stöllner 2009)(Krause 2009; Maddin 1988; Moesta and Schlick 1991)(Möslein 1999). What is presented here is an argument for a field-led research program investigating the evidence of production, rather than focusing solely on deposited metalwork. This information will also present a body of evidence from another region of Europe where evidence for the primary production of copper has been identified for comparison with the evidence recovered in Britain later in this thesis.

With the advent of the Bronze Age in the European alpine region metallurgy appears to have been a reasonably ephemeral task. Activities related to mining and mineral collection appear to have been occurring prior to the increased settlement in upland zones. This activity may have been conducted by members of lowland communities on a seasonal or occasional basis (Della Casa 2003; Kienlin and Stöllner 2009). Prior to the expansion of settlement in the inner alpine region at the close of the Early Bronze Age in the region, circa 1600 BC, it appears that raw copper [ore] was transported from the deposits in the Saalach – Salzac valleys in Austria to settlements at the mouth of the Alpine Valleys (Krause 2009; Menke 1982). This practice of moving to ore closer to the already inhabited region for further processing is evidenced in the treatment of the waste products. Slag tempered moulds and other ceramics have been recovered from Early Bronze Age settlement contexts in the lower parts of the inner alpine valleys (Krause 2009). Metalwork hoards, containing ring and rib ingots, have also been found in the immediate vicinity of these sites (Möslein 1999). The transport of the copper ore to these sites sits in contrast to later Bronze Age practices more broadly known in the western alps where numerous slag heaps are found in much closer association to the ore deposits around OberHalbstein, in eastern Switzerland (Krause 2009). By the close of the Early Bronze Age there is plentiful evidence that Chalcopyrite was being exploited in the Alpine region (Krause 2009).

There is substantial evidence for extractive metallurgy dating to the Early Bronze Age in the vicinity of the Mitterberg mining district (Kienlin and Stöllner 2009). Kienlin and Stöllner (2009) suggest that the earliest Bronze Age mining pattern was one of access to copper resources negotiated along kinship lines or within a wider community. Their proposal would see individuals living at a distance from mineral resources using kinship ties or community membership to gain access to copper resources with only small scale, possibly seasonal, exploitation taking place (Kienlin and Stöllner 2009). More intensive mining is dated to the later part of the Early Bronze Age (circa 1800 – 1600 BC) and is commensurate with the increase in upland settlement (Kienlin and Stöllner 2009). This is not necessarily a uniform pattern across entirety of the alpine region, but ample evidence indicates that in many of the inter alpine valleys ore mined in the Early Bronze Age was transported to settlements away from the source where there is indirect evidence for smelting, notably the slag inclusions in ceramics, and the production of metal objects.

The evidence of copper production in Alpine Europe is better known for the large-scale installations that characterize the process in the later Bronze Age (Doonan 1999; Moesta and Schlick 1991; Zwicker and Goudarzloo 1979); however, the evidence from the Early Bronze Age reveals a different set of practices with concentration of increased mining on more abundant or sustainable mineral resources, such as the Mitterberg region, developing through the Middle Bronze Age (Kienlin and Stöllner 2009).

2.2.3.2. The Iberian Peninsula

While evidence for primary production on the Iberian Peninsula, an area from which early Irish metallurgical traditions may have been inherited (O'Brien 2004), is not a new discovery (c.f. Rothenberg and Blanco-Freijeiro 1980; 1981), copper smelting slag has only recently been identified (Comendador Rey 1999). Unlike the Alpine region, Iberian metal mining and production do not seem to have developed into large-scale installations until quite late in the Bronze Age (Gilman 1987; Rovira 2002). Initially Renfrew (1969) proposed an independent genesis for metallurgy in Iberia; however, with revelations in the conduct of early metallurgical processes in Spain, Portugal and elsewhere in Europe the Iberian process cannot be considered to starkly contrast coeval practises elsewhere (Brandherm 2009; Comendador Rey 1999).

There are large and well known mineral reserves to be found on the Iberian Peninsula; however specialist sites relating to the further exploitation of these resources in the Bronze Age have not been forthcoming (Comendador Rey 1999; Rovira 2002). The evidence for copper mineral preparation and smelting from the Bronze Age in Iberia are, like those in Britain, less well known than other regions of Europe (Rovira 2002). It is the careful excavation of Early Bronze Age domestic sites in Spain that have provided direct, solid evidence of copper smelting in this region of Europe (Comendador Rey 1999; Rovira 2002). The evidence for smelting comes from the identification and analysis of slag formations on the inner surfaces of large open-mouthed ceramic vessels (Rovira 2002). In an alternative model for smelting, proposed by Rovira (2002), a very limited amount of slag is produced by the conscientious exploitation of a poly-metallic ore, such as the antimony rich fahlore, tetrahedrite. Although such a method of copper production would be possible with very little slag production, the interaction between the ceramic vessel and gangue was unavoidable, producing the slag adhesions to the ceramic crucibles.

The current model for early metallurgical practices on the Iberian peninsula focuses on small-scale exploitation of the plentiful mineral outcrops (Comendador Rey 1999; Gilman 1987) with what Rovira (2002: 12) has termed "a domestic system of production". The small ore deposits that appear to have been exploited in the Early Bronze Age are poly-metallic ores with high levels of arsenic and/or antimony (Müller and Pernicka 2009). When smelted these ores produced a natural arsenical bronze that benefited from many qualities similar to tin bronze (Müller and Pernicka 2009). This is might also present a reason that the adoption of tin bronze occurred so much later in Iberia than in Britain, despite the availability of tin in the region (Rovira 2002).

2.2.3.3. The Aegean

The Southern Aegean region was a focus for research on early metalworking (Betancourt 1970; Branigan 1968; 1974; Renfrew 1967; 1969; 1972). Recent excavations have revealed a wealth of new evidence for metal production enabling further exploration of the process. Models being developed on new data include the composition and distribution of metallurgical sites and their relationship to other Early Bronze Age sites (c.f. Day and Doonan 2007). The amount of direct evidence for primary metallurgy that has been recovered in the Aegean is staggering in comparison to that from the rest of Europe. Furnace structures across the region in this period were most likely 'small bowl furnaces constructed as hollows in the ground' as seen at Chrysokamino on Crete (Betancourt 2007) and at Kythnos (Catapotis and Bassiakos 2007; Stos-Gale 1998). These were topped by freestanding cylindrical or truncated cone shaped chimneys which were perforated in irregular patterns every few centimetres (Bassiakos and Philaniotou

2007; Betancourt 2007). Slag found covering smelting sites in the region is finely crushed with larger fragments only a few centimetres across (Betancourt 2007; Catapotis and Bassiakos 2007).

Evidence for primary copper production in the Cyclades and on Crete in the Early Bronze Age invokes a process that was spatially fragmented (Doonan and Day 2007). Raw copper ore and stone tools, which would be needed to process the ore and remove the waste rock are absent from smelting sites (Betancourt 2007). Also absent is evidence of secondary production. There are no crucibles, mould fragments or finished products found at the smelting sites (Betancourt 2007). This indicates that mining and ore processing were undertaken at different sites, away from the smelting site, as was secondary production.

Relationships to other coeval sites are less clear and a regular pattern has not emerged. Metal production sites on Kythnos, for example, do not show a clear relationship to settlement sites and instead display a connection to possible mineral sources, albeit at distances between 400 and 1000 m (Bassiakos and Philaniotou 2007). On the other hand, no mineralization has been identified in the area of Chrysokamino on Crete, which is atop a coastal cliff and roughly 600m from a 'domestic complex' (Betancourt 2007; Catapotis and Bassiakos 2007). In both cases, their location, on isolated and exposed promontories, is in keeping with a general pattern observed in the Aegean and beyond (Craddock 1995). Catapotis (2007) has suggested that the lack of a regularly patterned distribution for smaller smelting sites is a product of continuous movement to exploit surface exposures of ore. Larger smelting sites, such as Skouries or Kephala on Kythnos, represent a more permanent installation with ore transported to the site (Catapotis 2007).

Further evidence for primary copper production in the Cyclades and on Crete at the end of the Early Minoan Period portrays a process that was intentionally obscured. Alongside the evidence for spatially discrete stages in the production process, chemical analysis of the slags indicate that ores from more than one source were smelted together in the same furnace (Catapotis and Bassiakos 2007; Doonan and Day 2007; Stos-Gale 1998). This spatial fragmentation of the process and the intentional mixing of ores may allude to conceptions of the origins of metal in the Bronze Age of the region (Doonan and Day 2007). Combining material from a dispersed landscape in the furnace denies a one to one relationship between the metal produced and a specific source, in effect denying a single origin, which is further represented by the disarticulation of the stages of primary production (Doonan and Day 2007).

2.2.3.4. Ireland

Evidence for primary metallurgy in Ireland is largely concentrated in the Southwest, in Counties Cork and Kerry. Mineral extraction sites dominate the body of evidence, but again through careful field led investigation fragments of evidence from the full range of primary copper production have been recovered. The largest concentration of Bronze Age mine workings are found in County Cork, on Mount Gabriel. At the time of writing, eight of the potential thirty-two workings on Mount Gabriel had been radiocarbon dated to the Early Bronze Age (Jackson 1968; 1984; O'Brien 1987; 1994). The mines on Mount Gabriel are part of a tradition of mining marked by 'Mount Gabriel Type' workings found across the Mizen, Beara and Ivernian Peninsulas in southern County Cork (Jackson 1980; O'Brien 1990; 1994). These so-called 'primitive' workings focus on the exploitation of secondary minerals, such as malachite.

Evidence for mineral separation was also found at Mount Gabriel during the excavation of Mines 3 and 4 and the associated work areas (O'Brien 1994). Excavation of the tip associated with these workings revealed that the finely crushed waste material within the tip was practically devoid of any copper mineral (O'Brien 1994). Postholes located adjacent to the mining waste have been interpreted as the remains of a sheltering structure in the vicinity of a stone slab used for crushing and separating the ore (O'Brien 1994). A trough, located in the vicinity of the working area, may have provided a source of water although there is also a small stream in the same vicinity (O'Brien 1994).

Evidence for the earliest copper mining in Ireland comes from Ross Island, a site situated just to the north of the Devonian sandstone that hosts the Mount Gabriel-type mines (O'Brien 1994), in an area of carboniferous limestone (Kinnaird and Nex 2004). The mines take advantage of the Ballysteen formation, a poorly bedded dolomitized limestone structure (Kinnaird and Nex 2004). These mines exploited a poly-metallic ore, tennantite, which is similar to several known fahlore ores on the Iberian Peninsula (Almagro-Gorbea 1995; O'Brien 1995; 1999; 2004). The initial use of this arsenic rich copper ore may represent a particular or pre-existing knowledge of the properties of this type of ore (O'Brien 1999; 2004). The tennantite ore exploited at Ross Island in the only ore thus far to have a unique enough trace element signature to provenance metals using this method. The mines at Ross Island the only Bronze Age mines known to date that could produce metal types A and possibly F as identified by Northover (1980a; 1980b; 1989).

Besides early mining, Ross Island is the most complete metallurgical site excavated to date in the British Isles. The site features evidence for mineral separation and the heat alteration or smelting of copper ore. The habitation site found on the western ledge above the mines was in essence covered with a non-uniform layer of crushed gangue (O'Brien 2004). This material was not deposited in a single event, or continuously, but represents the re-tasking of different areas within the site over the duration of its use (O'Brien 2004). An area of silts and finely crushed copper ore focused in the vicinity of pit features, related to additional metallurgical activity, show the concentration of copper ore at the site (O'Brien 2004). The Pit Features themselves are "… important evidence of on-site metallurgy" (O'Brien 2004: 466). There are ten oval pit features, with a Beaker or Early Bronze Age association, of which seven appear have been used in metallurgical processes (O'Brien 2004). There is no evidence for fire reddening on the sides or bottom of these features, but the edges appear to have experienced intense burning. Pure quartz sand, an excellent flux for the ores found at Ross Island, charcoal and fuel ash were all present in the fill of several of these features and in a spread in the adjacent area (O'Brien 2004). Fragments of heat altered copper ore were also recovered from the area of these pit features are indicative of the heat transformation of sulphide ores at the site (O'Brien 2004). The pattern of intense burning on the sides of several of the pit features, but not the base is likely the result of smelting copper, which would be heated from above, leaving this distinctive pattern.

A second site that has produced evidence for Early Bronze Age smelting is Ballydowny, in County Kerry, Ireland. The site consisted of three separate areas, each of which contained slag. These were all initially identified as the residues of Medieval iron smelting and smithing; however, recent radiocarbon results have re-dated one phase of activity to the Early Bronze Age [2030-1870 BC] (Fairburn 2009), coeval with the final phase of mining activity at Ross Island (O'Brien 2004). Reassessment of the slag from this context by Dr, Chris Salter has confirmed it to be the result of copper smelting with an iron rich, silica poor composition atypical of copper slags elsewhere (Fairburn Pers Comm.). It would appear that lime was used in place of silica producing a calcium ferrite slag (O'Brien 2004; Salter unpublished report). The copper prills encased in the slag appear to have a composition within the As/Sb/Ag elemental range observed in metals produced from the ores at Ross Island (O'Brien 2004). The slag assemblage from Ballydowny consists of a single plano-convex piece weighing 500g that was found associated with a fragment of Bronze Age pottery and fragments of a grinding stone (Kiely and O'Callaghan 2009). No structural evidence for copper smelting activity has been recovered at Ballydowny.

2.2.3.5. A British Proposal: A low or Non-Slagging Model

The proposals of non-slagging, low slag or solid-state reduction of copper minerals to copper ore (Craddock 1990b; 1995; Craddock and Meeks 1987; Pollard *et al.* 1990; Timberlake 2005) is a product of the scarcity of evidence for primary production in Britain. Craddock (Craddock 1989; 1990b; 1995; Craddock and Meeks 1987) originally proposed the use of low temperature and 'primitive' methods for metal production in the British Bronze Age based on indirect evidence gleaned from the analysis of metalwork. The iron content of the Early Bronze Age metalwork in Britain, as with early copper and bronze in contemporary Europe, is significantly lower than the levels seen in the metalwork of the later Bronze Age civilizations of the Mediterranean and Near East (Craddock 1990b; Craddock and Meeks 1987). Craddock (1990b) argued that elevated levels of iron in copper objects is a result of a well-developed slagging process and that molten copper is infused with iron when it is in contact with molten slag, the latter having significant levels of iron oxide. The level of iron in bronze objects in the British Iron Age is significantly higher than the metalwork from a millennium earlier and is therefore argued to represent either a more developed domestic smelting technology, or metal imported from a region with such a smelting tradition (Craddock 1990b).

Non-slagging processes and solid-state reduction are dependent on carefully regulated variables that are more often recreated in laboratory settings (Bachmann 1982). In order to restrict the interaction between metal, gangue, and the ceramic lining of a furnace or crucible, similar to that observed on the wide open mouthed crucibles from the Iberian Peninsula, the furnace temperature has to be carefully regulated while still maintaining a high enough temperature to reduce copper ore to copper metal (Bachmann 1982). In this type of reduction only ores with a very high percentage of copper, better than 60%, would be viable (Bachmann 1982; Craddock 1989). It would be likely that a small amount of slag-like material would be produced in the reaction; however, due to the lower temperatures it may only be semi-fused and would therefore be easily destroyed to recover any metallic copper within (1989; Craddock 1990b; 1995; Timberlake 2005).

2.3. Summary

Metalwork is one of the lasting elements of the material culture of the Bronze Age. It is therefore an important part of the assemblage that archaeologists study to recreate Bronze Age production; networks of exchange; and social organization and reproduction in Britain and Ireland. This material has traditionally been approached in one of two ways. Subjectively, the context in which the objects have been found forms the basis for modelling social identities of the producers, the consumers and those who may have been involved in the networks of exchange prior to the end of the objects lifecycle. The focus begins from the context of consumption and works backwards through systems of exchange and interaction using typological distributions as an interpretive tool. Objectively, archaeometallurgical specialists poke, prod and analyze artefacts to understand their production and use. The object of study is the consumed artefact that, following its production and use, was chosen for deposition and intentionally removed from circulation.

The production of metal and metalwork can be seen as two interconnected, but distinct sequences. The smelting of copper contributes to the available pool of metal through the creation of new material. The biography of that material does not end when the metal is cast into an object, but will likely continue through several castings. The casting of objects consumes a quantity of the available metal, but does not remove it from circulation as that metal can be freed and reused ending the lifecycle of that object. The deposition of a metal object reflects a conscious choice to consume both object and material in effect ending the lifecycle of the object and the biography of the material. However, as shown above modern analytical methods are not able to penetrate beyond the lifecycle of a metal artefact to understand the production and biography of the metal crystallized within.

Field-led archaeology has successfully identified the traces of primary copper production in other regions of Europe. Once the basic knowledge of the metallurgical process had been gained, archaeological evidence points to many regional variations indicating adaptations of the learned process to fit local resources and cultural styles and beliefs. The same cannot be said for Britain, where the archaeological evidence for primary copper production remains almost completely unexplored, despite a rich tradition of archaeological investigation in other Bronze Age arenas.

In Britain, archaeologists have chosen to focus on other elements of the archaeological record, over what are all to often regarded as merely 'technological' sites (Doonan 2008). However, in order to begin to approach primary metal production, rather than consumption, it becomes necessary to engage with the *chaîne opératoire* and explore the stages and related materials involved with mining and smelting. The growing evidence for mineral extraction in the Early Bronze Age of Britain and Ireland form one part of the operational sequence, or *chaîne opératoire*, involved in the primary production of copper metal. The next chapter (Chapter 3) will engage with this *chaîne opératoire* and explore the existing evidence relating to the making of copper metal that exists within Britain. This information will then be used to inform original fieldwork and survey.

3. Primary Metallurgy: Evidence and Practice

3.1. Introduction

Following the cursory review of both the evidence for and interpretive potential in archaeological evidence for primary copper production in other regions of Europe, this chapter will engage with the field evidence for primary production found in Britain within a framework of an operational sequence. There are two key aims in applying a *chaîne opératoire* approach. The first is to reframe the archaeological remains and seek to understand the static evidence in terms of the dynamic practices with which they were associated (Wager 2001c). This should not be seen an attempt to establish principles or theoretical laws with which to compare the organization of both contemporary and past communities based on material remains as practiced under the New Archaeology (Binford 1962; 1972; Binford and Binford 1968). The focus here is on individual practice(s) and uses an embodied approach to consider the evidence of discrete albeit linked activities (Wager 2001c). It is through the motions and actions of the individual, or individuals, that the archaeological remains were formed; therefore analysis of the evidence is approached using the human body as a medium (Dobres 2000; Edmonds 1990; Leroi-Gourhan 1993 [1964]; Wager 2001c).

A *chaîne opératoire* based research methodology provides detailed empirical observations from an artefact, or artefacts, that relate to its making and use (Dobres 2000). It can also be tailored the specifics of different research agendas, materials and the nature of their manipulation. The analytical methods of a *chaîne opératoire* approach provide a valuable avenue through which to examine the choices made by the craftsperson (Dobres 2000; Wager 2001b) and when applied to metallurgy affords a unique insight into the specific practices with which it was associated. Metallurgy employs specific materials that need to be exposed to specific conditions in order to be successful. The ways in which these needs are met are culturally constructed, but he precise conditions can leave very specific signatures in the materials encountered by archaeologists at all levels, ranging from the landscape to the atomic, witnessed through geochemical and micro-structural analysis (Jones 2002).

The *chaîne opératoire* also considers more than the immediate or a single process that might result in the object(s) under study. A *chaîne opératoire* approach examines the sequential processing and use of material and object that relate to the socially constructed crafting process as well as they ways the resulting artefacts were considered and used (Dobres 2000; Edmonds 1990; Wager 2001b). This speaks to the second aim of employing a *chaîne opératoire* approach, which is to consider the evidence for metal production beyond the event of smelting. The concept of *chaîne opératoire* typically encompasses the entirety of an objects biography from material sourcing through manufacture and use to the deposition or discard of an object (Dobres 2000; Edmonds 1990; Leroi-Gourhan 1993 [1964]). A consideration of biography complements this research, which is aimed at investigating the sequence of tasks, from the acquisition of material to the making of metal and is an extension of the socially embedded interaction between agent and object or material, observed above, that is the core of the *chaîne opératoire*. It is this repeated interaction that results in the emergence of a *habitus* (Bourdieu 1977), a familiar social practice that informs or influences future practice, and communicates social meaning.

As seen in chapter two the metallurgical *chaîne opératoire* is divisible between the making of the material and the casting of that material into an object, or primary and secondary production. Because of the transformative nature of copper metal production and manipulation, following the total operational sequence of a specific volume of the metal through subsequent casting events would be very difficult. As this thesis focuses on primary production this chapter will only engage with the *chaîne opératoire* related to the making of copper metal, and not to copper objects. The evidence for mineral extraction, processing and smelting currently available in Britain will be integrated in to the discussion alongside information gleaned from experimental archaeology.

3.2. Prospection

The detection of ores in prehistory likely involved the identification of minerals on the basis of physical characteristics, the most obvious of these are colour and density (Charles 1967; Ottaway and Roberts 2008). The initial identification of minerals would have been dependant on two things. First, previously unknown mineral deposits had to outcrop at the surface or in places visible and accessible to individuals involved in the task of prospecting (Timberlake 2001b). Secondly, the identification of mineral outcrops is dependent on the ability of the individual to identify desirable minerals (Ottaway and Roberts 2008).

Mineral ores are not resources that are only recognized with the introduction of metallurgy. The bright colours of the secondary copper ores malachite and azurite in particular made them attractive materials for use in decoration and adornment. Examples of bright blue and green pigment made from these minerals have been found predating their metallurgical use in southeast Europe (Glumac 1991; Glumac and Todd 1991; Jovanovic 1980a; Jovanovic 1980b; Krajnovic and Jankovic 1995) and near east (Bar-Yosef Mayer and Porat 2008; Solecki *et al.* 2004). The use of secondary copper ores for beads and pendants or amulets can also be seen to predate the making of copper metal in the Near East (Bar-Yosef Mayer and Porat 2008; Solecki *et al.* 2004) and southeast Anatolia (Hauptmann 2007). Examples of malachite beads have also been recovered from the site of Belovode in eastern Serbia southeast Europe, although these are coeval with metallurgical activity at the site (Radivojevic *et al.* 2010).

Once metals became known the identification of mineral deposits may have been aided by the presence of native copper in association with suitable copper ores, though this may not be the case in Britain (Ottaway and Roberts 2008). The presence of native copper at mining sites in Britain is difficult to confirm owing to the destructive nature of its extraction and no objects made of this material have been identified. Mineral bearing rock may also have been identified in stream or riverbeds as placer deposits, mineral-bearing rock eroded from the source and carried downstream (Ottaway and Roberts 2008; Timberlake 2002a), or through the precipitation of secondary minerals in springs flowing through mineralized areas (Timberlake 2009).

The identification of mineral outcrops ultimately depends on a practical knowledge of the characteristics such as the density and colours of different ores (Charles 1967; Ottaway and Roberts 2008; Timberlake 2009). Knowledge of the properties of different rock types was not new to the Bronze Age. Familiarity with the properties of different flints as well as volcanic and other igneous or metamorphosed rock types in Britain is well attested in the preceding Palaeolithic, Mesolithic and Neolithic periods (Conneller 2008). The identification of desirable resources depended on visual recognition and trials of the material by flaking or crushing of rocks as it could have been with later minerals (Timberlake 2009).The colour may also have been linked to other properties of the ore which may have been viewed as more or less desirable resulting in its exploitation or rejection (Ottaway and Roberts 2008).

Copper Oxides			**Fahlores**		
Tenorite	CuO	Black	Tennantite	$Cu_{12}As_4S_{13}$	Black / Grey
Cuprite	Cu_2O	Red	Tetrahedrite	$Cu_{12}Sb_4S_{13}$	Black / Grey
Copper Carbonates			**Copper Sulphides**		
Azurite	$2CuCO_3Cu(OH)_4$	Dark Blue	Covellite	CuS	Blue
Malachite	$CuCO_3Cu(OH)_4$	Emerald Green	Chalcocite	Cu_2S	Grey
Copper Silicate			Bornite	Cu_5FeS_4	Silver / Grey / Distinct
Chrysocolla	$CuSiO_3H_2O$	Turquoise blue	Chalcopyrite	$CuFeS_2$	Brassy Yellow

Table 3. 1 Common copper minerals by colour (after Charles 1967; Ottaway & Roberts 2008)

In Britain, evidence of Mesolithic activity at Alderley Edge, in Northern England, coincides with areas of early malachite and azurite extraction (Timberlake and Prag 2005), although there is no direct evidence that these are coeval. Copa Hill, in central Wales, has also returned a number of radiocarbon dates for the third and fourth millennium BC relating to the earliest phase of mineral extraction

(Timberlake 2003b). Pre-existing knowledge of mineral deposits cannot be demonstrated at all copper mines and prospection was likely an activity that was carried out alongside the exploitation of known ore sources. Timberlake (2001b; 2002a; 2009) suggests that prospection was a natural complement to pastoralists who would have been able to identify and explore mineral outcrops whilst grazing animals in the highland zones of Wales and northern England. Changes in land use resulting in woodland clearance and deforestation to open up pasture may also have exposed mineral outcrops (Timberlake 2009). The removal or erosion barriers through the repeated burning and clearing of tree cover on hillsides in upland areas may have inadvertently led to the exposure of previously buried mineral beds.

Once a copper deposit had been identified the next stage was to extract the ore. As presented above, the exploitation of surface outcrops was established in parts of the Near East and Europe prior to the use of metal and recent evidence from Britain alludes to the use of mineral resources in advance of copper metallurgy (Timberlake 2003b; Timberlake and Prag 2005). Over the course of the Early Bronze Age the development of specific mining sites was a feature of landscapes in Ireland, England and Wales. However the continued search for, and expedient or opportunistic exploitation of, smaller deposits and outcrops may have been common practice.

3.3. Extraction

The initial use of minerals was likely dependant on the collection of ores from surface outcrops as seen on the Iberian Peninsula (Rovira 2002; Rovira and Ambert 2002). Additional evidence for the extraction of minerals and native copper predating the Bronze Age can been seen at Rudna Glava, in Serbia (Jovanovic 1978; 1980b) and Aibunar, Bulgaria (Chernych 1978). Similar evidence is not readily available in the British Isles and no secure contexts for the exploitation for copper minerals in the Mesolithic or pre-metal Neolithic of Britain have been identified. However, the earliest pre-Bronze Age dates recovered from Copa Hill (Timberlake 2003b) show at least a familiarity with this place prior to the use and production of copper metal. The special association between Mesolithic domestic refuse and as yet undated mineral extraction features at Alderley Edge (Timberlake and Prag 2005) is a tenuous connection, but again shows at least familiarity with a site later exploited in the production of copper. The discovery of hammer stones in regions where mineral outcrops occur, but larger mining sites have yet to be identified, such as Warton in Lancashire (Penney 1978) and Langness on the Isle of Man (Doonan and Eley 2000; 2004) may relate to the continued exploitation of surface outcrops on an occasional or expedient basis. Much of the direct evidence for small-scale surface extraction may have been lost in the development of a Bronze Age mining site, or during more recent mining ventures (Briggs 1988; Burl 1976; Ottaway and Roberts 2008).

The identification of mining activity becomes much easier at sites that were exploited repeatedly through the Bronze Age. Over time the repeated extraction of ore meant that Bronze Age miners delved more deeply into the subsurface ore body, constructing a site through the removal of material and the deposition of waste in mounds or spoil tips. Pit mines at Alderley Edge (Gale 1989; Garner *et al.* 1994; Mullin 2003; Roeder 1901; Timberlake and Prag 2005) and opencast mines such as Copa Hill (Davies 1947; Hughes 1981; Timberlake 1987; 2003b), Nant Yr Eira (Timberlake 1990c), and Nantyrarian (Timberlake 1995b) would have become visible features in the Bronze Age landscape. Even the larger mining complexes in Europe have a possible parallel in scale in Britain at the Great Orme (Dutton 1990; Dutton and Fasham 1994; James 1988; Lewis 1994; Wager 2001b).

Underground workings have been positively identified at the Great Orme (Lewis 1990b), the site which has seen the most extensive archaeological investigation to date; however, Parys Mountain has also recently been the site of discovery of subterranean mine working that potentially dates to the Bronze Age (Jenkins 1995; 2003). Early reports from Ecton Hill also hint at the potential for underground workings. Kirkham (1947) reported exploring an underground chamber with stone hammers and antler tools in situ. The antler tool used to date the site was recovered from an underground context (Barnatt and Thomas 1998) and a hand written note attached to hammer stones in the Bateman collection indicates that they had also been recovered from subterranean contexts (Pickin 1999).

Mining, as with any activity, was a dynamic process involving the cooperation of an active agent and appropriate tools. It would have begun with the collection of suitable material for the tools and its subsequent modification and transport to the mine. Once at the mines a number of actions may have taken place. If fire was used to weaken the rock of the working surface then even more material had to be brought into the site and arranged. Following the fire the ash and partially or uncombusted fuel, would also have had to be cleared from the working surface. This might have involved a raking action to pull small fragments of material together for collection and removal or away from the working area. The initial working of the mine may then have involved the use of prising tools to work pieces of rock and mineral free. This may also have included soft percussion to drive wedges and chisels into the cracked surface. As the weakened stone was removed repeated percussion, using the hammer stones, may have been used to batter the working surface. Following the successful removal of material it had to be collected and transported. The activity at a mine may have depended on any, or more likely, a combination of all these actions and more. It would have been laborious, physically demanding work.

It is in the developed later stages of the mines as they deepened, perhaps developing even into underground spaces, where the positioning and working of the body become most tangible. In these restricted spaces the idea of a shared corporeal existence, expressed in the application of *chaîne opératoire* allows the modern visitor to inhabit the same space as the early miner. It is here that the movements of the body, the restriction of access to and movement within a working space are most apparent. As mines delved deeper they become more removed from a familiar inhabited world forcing the miner into an underground realm where they had to conduct the same actions, but in a far different space. Access to the working faces of the mines may have involved contorting the body to squeeze through restricted passages or working from unfamiliar positions, which limited the range motion. In this environment the act of mining may have become more than physical labour, but mentally challenging as the miners moved into increasingly strange and limiting surroundings.

3.3.1. Dating and Distribution

In the absence of absolute dates, the identification and dating of old copper workings presents a particular challenge in Britain. There is a near total absence of characteristic Bronze Age material culture found at copper mines; however in the course of mineral exploration and extraction during the post-medieval period (peaking in the 18th and 19th centuries), miners at a number of sites in England and Wales encountered hammer stones and old stopes or workings. As early as 1744 antiquarians suggested that these 'owld man' workings were mined using the stone and bone tools by 'pre-iron using people' (Sykes 1790 reproduced in Briggs 1976; Morris 1744 as in Timberlake 2001a). Antiquarians took an early interest in the discoveries of the miners, and visited many of the sites, including the Great Orme where Lord Stanley observed: a cavernous space complete with bone and stone tools, that had been worked to exhaustion whilst metallurgy was still in its infancy (Stanley 1850). The antiquarian accounts are the only surviving record of several early mine features owing to their subsequent destruction. The chamber originally visited by Lord Stanley was devastated by blasting within three months of its initial discovery (James 1988; Stanley 1850).

While many antiquarians ultimately concluded that the early mining remains were Roman or Romano-British (Evans 1872; Stanley 1850; Stanley 1873), their records and journals have formed the foundations for more recent explorations of early mining. The first archaeological project on early mining was led By Oliver Davies who, under the newly formed British Association for the Advancement of Science conducted exploratory excavations at a number early mine workings in Wales. Although Davis concluded that the earliest mining on the Great Orme headland, in Cwmystwyth at Copa Hill, and at the sites of Nant Yr Eira and Parys Mountain were Roman or 'Old Celtic' in origin (Davies 1937; 1938; 1939; 1947; 1948) his work added to the antiquarian knowledge base of early mining sites that continues to inform the archaeology of prehistoric copper mining in Britain (Briggs 1988; 1991;

Craddock 1995; Crew and Crew 1990; O'Brien 1996; Timberlake 1987; 1988; 1992a; 1992b; 1994; 1998; 2001a; 2001b; 2009).

There are approximately a dozen copper mines in Britain that have now been radiocarbon dated to the Bronze Age, the majority of these date to the first millennium of metallurgy in Britain. Interest in the possibility of identifying Bronze Age Activity at mining sites increased after the successful radiocarbon dating of shallow drift workings found at Mount Gabriel, located on the Mizen Peninsula in the south of County Cork, Ireland (Jackson 1968; Jackson 1984; O'Brien 1987; O'Brien 1990; O'Brien 1994). Excavations of mine 5 / 6 spoil by Jackson (1968) produced the first radiocarbon date for copper mining in the Bronze Age (3220±90 BP). Although this date was subsequently revised to 3450±120 (Felber 1970; Jackson 1984) the identification of an Early Bronze Age mine working sparked renewed interest in sites originally recorded by antiquarians in Britain.

Initial scepticism over the potential recovery and dating of mining evidence from the Bronze Age (Briggs 1983; Briggs 1988) has since been addressed through the excavation and dating of additional drift workings at Mount Gabriel (O'Brien 1987; O'Brien 1994) and at several sites in Britain (Ambers 1990; Barnatt and Thomas 1998; Dutton 1990; 1994; Garner, et al. 1994; Hedges, et al. 1994; James 1988; Jenkins 1995; Lewis 1990b; 1994; O'Brien 1995; 2004; Timberlake 1988a; 1988b; 1990a; 1992a; 1995; 1996b; 1996c; 1996d; 2003b; Timberlake and Prag 2005; Timberlake and Switsur 1988).

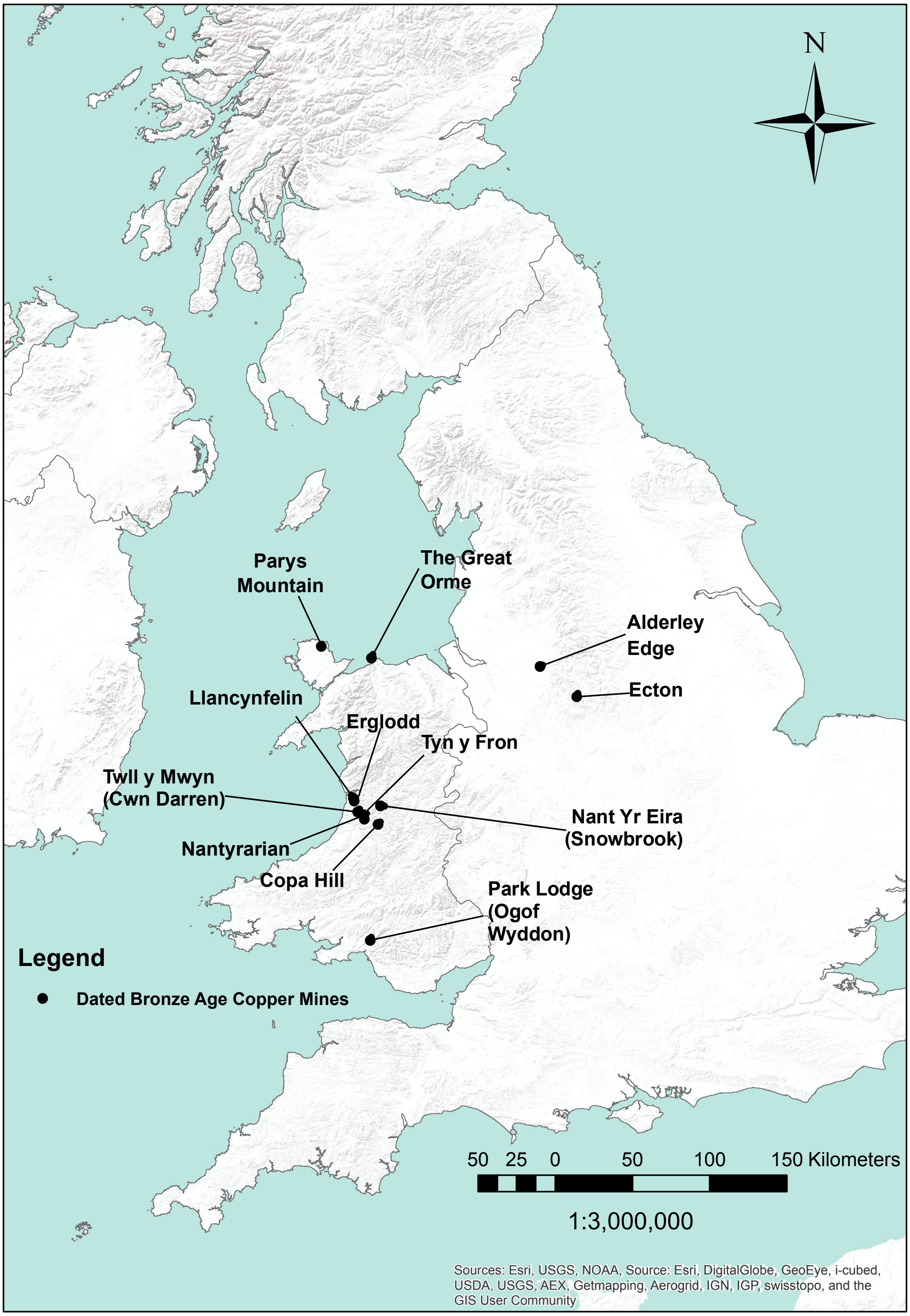

Figure 3. 1 Distribution of dated Early Bronze Age copper mines

Early Bronze Age activity has been established at almost a dozen copper mines using radiocarbon in England and Wales. The dates have been obtained from a range of materials including charcoal, bone, antler and waterlogged wood recovered during the excavation of sites (Ambers 1990; 2003; O'Brien 1994; 2004; Timberlake 1996c; 2003b). These date ranges confirm activity at these sites within the Bronze Age, with a number of dates clustering in the earlier Bronze Age. The Great Orme mines have produced dates that extend the evidence for mining activity into the later Bronze Age (Ambers 1990; Dutton and Fasham 1994; Lewis 1994).

The complexity of identifying and dating early mining sites in the absence of absolute dates remains an issue. This problem is not unique to Britain. In Ireland, as seen in the previous chapter, only eight of the drift workings on Mount Gabriel Have been radiocarbon dated to the Early Bronze Age (Jackson 1968; 1984; O'Brien 1987; 1994). The remaining drift workings are, however, believed to be roughly contemporaneous based on peat growth, shared formation processes and recovered material (O'Brien 1994). These same principles have been applied in Britain with similar formation processes and material culture, notably hammer stones, being used to tentatively identify mining sites with possible Bronze Age components.

The greatest number of the morphologically early copper mining sites in Britain has been identified in Wales. These sites are largely based on antiquarian reports and the site visits of Oliver Davies (Davies 1937; 1938; 1939; 1947; 1948). More recently the Early Mines Research Group (EMRG) has endeavoured to explore many of the sites identified in early sources, which has resulted in the dating of several including: Nant yr Eira, Tyn y Fron, Llancyfelin and the Nant yr Arian Mines (Timberlake 1988; 1990b; 1992a; 1995; 1996b; 1996d). Excavation on the majority of these sites has been limited and the primary goal has been to identify Davis' excavations, evidence of early mining techniques and to recover suitable material for radiocarbon dating.

Figure 3. 2 Distribution of undated early mines and hammer stone finds

Many additional sites remain undated in the welsh highlands, but have been identified by the distribution of hammer stones (Timberlake 2001b; Timberlake 2002b). It is these hammer-stones that appear to be truly unique to mines predating the use of iron. All sites at which hammer stones have been reported and that have thus far been radiocarbon dated have returned dates within the Bronze Age. A speculative conclusion is that stone tools were completely replaced by iron as it became available (Craddock 1989). Despite caution advised by Briggs (1983) and others (Davey *et al.* 1999), stone hammers have been used as indicators of the antiquity of mines in the absence of absolute dates or other datable material (Craddock 1989; Doonan and Hunt 1999; Jackson 1980). Craddock (1989; 1995) has argued that the hammer stones should be accepted as tentative evidence of Bronze Age activity on the basis that: "mines which have their earliest phases post-dating the Bronze Age do not yield the stone mining hammers" (Craddock 1989: 183). Subsequent excavations have only strengthened the association between hammer stone tools and pre-iron or Bronze Age mining. The presence of hammer stones has been used to suggest Bronze Age exploitation at several mines in Wales and on the Isle of Man (Doonan and Hunt 1999; Jackson 1980; O'Brien 1989; Pickin 1990; Pickin and Worthington 1989; Thorburn 1990; Timberlake 1994).

Hammer stones have also been found in a number of regions around Britain that are known to have copper deposits, but where Bronze Age mines have yet to be identified. In Lancashire, a region that hosted an Elizabethan copper industry (Donald 1955), a single hammer stone was found incorporated into a stone wall near Warton (Penney 1978) and may indicate much earlier copper exploitation in that region. Hammer stones have also been found in association with copper bearing ores on the Isle of Man, which has supported a copper mining industry since at least the 13^{th} century (Davey *et al.* 1999). The first reported hammer stones were recovered in association with more recent mining features on Bradda Head (Pickin and Worthington 1989), a headland that projects into the Irish Sea from the southeast coast of the island. The mines of North Bradda remain unexplored, but display features in common with morphologically early mines elsewhere (Doonan and Hunt 1999). A subsequent pedestrian survey of the Langness peninsula, projecting from the south coast of Man, resulted in the recovery of an additional eight hammer stones loosely associated with areas of copper mineralization (Doonan *et al.* 2001; Doonan and Eley 2000; Doonan and Hunt 1999).

Figure 3. 3 Distribution of hammer stone finds

Despite the rich mineralization and mining heritage, no secure evidence of early mining activity has been recovered amongst the later mining remains of Cornwall. However, nine cobblestones that appeared to show traces of use-wear were recovered from an opencast trench at Wheal Coates in the vicinity of St. Agnes (Budd and Gale 1994). Although the use of stone tools, including three mortar stones that were used in the crushing of ore, alludes to the possibility of pre-iron mining activity (Craddock 1995), survey of the trench did not reveal significant evidence for early mining (Budd and Gale 1994). Hammer stone tools and other traces of mining are also poorly known in Cumbria and southeast Scotland, regions that hosted more recent large-scale mineral extraction. Stone hammers of unknown provenance are housed in the Keswick museum and old surface workings have been noted at Coniston (Timberlake 1992b), but no direct evidence for Bronze Age exploitation of mineral deposits have been identified. The mineral deposits of the Leadhills in southeast Scotland have previously been linked with Bronze Age gold mining (Blick 1991; Timberlake 1992b). Copper is also present in this region and objects found in Scottish museum collections may have been mining hammers (Roe 1967; Timberlake 1992b), but again no direct connection to Bronze Age copper mining can be made.

With the absence of characteristic Early Bronze Age material culture at sites relating to copper extraction and mining, relative associations are difficult to make. A definitive dating of the sites relies on the recovery of suitable material for radiocarbon or other absolute dating methods. However, increasing familiarity with the materials and formation processes of dated Bronze Age copper mines has enhanced the potential for suggesting a broadly coeval date at morphologically similar mines where suitable material for absolute dating has yet to be recovered. The materials and methods used to create these sites and that are now used to interpret the mining practices of the Early Bronze Age are explored below.

3.3.2. Mining Methods and Materials

Bronze Age mines depict an activity that was undertaken with great care to limit, as much as was possible, the extraneous removal of material; the goal was to facilitate access to and extract the mineral ores as efficiently as possible (Dutton and Fasham 1994). This means that the development of the mines followed the mineralization closely and effort was directed at winning ore with the unnecessary removal of the surrounding rock limited to only what was necessary for continued access. The remains of the trench mine at Copa Hill show that while great care was taken to extract as much of the ore as possible, the work concentrated in mineralized veins and avoided the unnecessary removal of the surrounding host rock (Timberlake 1990a; 1996a; 2003b). This is again reflected in the subterranean mines of the Great Orme. Many of the possible shafts on the headland are extremely narrow, big enough for only a small adult or child to move through following faults and mineral veins (Lewis 1994; 2001b; Wager 2002), although some of these may in fact be solution features in the Orme's karst environment and not related to mineral extraction (Wager 2001b). The conservative nature of Bronze Age mining is likely a choice made by the miners based on the tools they had to work with and the material they were attempting to create pathways through, or into, in order to remove the copper ore. This conscientious approach is further exemplified in the prehistoric spoil tips. Bronze Age mining spoil is generally finer grained and well sorted owing to the mining practices and a desire to separate out as much ore from the sterile gangue material as possible (Lewis 1994; O'Brien 1994; O'Brien 1996; Timberlake 2003b; Timberlake 2009; Timberlake and Barnatt Forthcoming). The spoil tips often include charcoal, collected following characteristic 'fire-setting' of rock faces, hammer stone spalls, and discarded hammer stones (O'Brien 1996; Timberlake 2002a; Timberlake and Barnatt Forthcoming).

Mineral extraction is preceded at many sites with the use of fire setting. This is a practice where by a large bonfire is built against the rock face and let to burn. The heat causes expansion of the rock, weakening and cracking the solid wall (Agricola 1950 [1556]; Craddock 1995; Lewis 1990b; O'Brien *et al.* 1990; Timberlake 1990e). It may also have involved the use of water to quench and rapidly cool the rock face causing the stone to contract (Timberlake 1990e). It is then possible to remove fragments with less physical exertion. This practice leaves smooth and rounded wall profiles that are common amongst Bronze Age mines (Lewis 1990a;

Lewis 1990b; O'Brien 1990). Large accumulations of charcoal at many of the mining sites also attest to the use of this practice and have been used to date many of the mines to the Bronze Age (Ambers 1990; Jackson 1968; 1984; James 1990; Lewis 1990b; 1994; O'Brien 1987; 1994; 1990a; Timberlake 1990c; 1995b; Timberlake and Mason 1997). Fire setting also alters the colour of the rock face and causes it to deform, developing a concave surface. This deformation and a reddening discolouration are still observable at some of the mines where this technique was employed such as Copa Hill (Timberlake 2003) Nant Yr Eira (Timberlake 1990c) and the Great Orme (Dutton 1990). Fire setting was not employed at all Bronze Age mines, nor was its use limited to the Early Bronze Age (Agricola 1950 [1556]; Briggs 1983; Briggs 1988; Timberlake 1990d). The use of fire was common mining practice in many countries prior to the use of explosives (Agricola 1950 [1556]; Barnatt *et al.* 1997; Claris and Quartermaine 1989; Timberlake 1990e).

During the first millennium of mining, the tool kit included stone, bone, antler and even wooden tools (Craddock 1995). A wooden shovel was recovered from Alderley edge in the latter part of the 19th century and was finally radiocarbon dated over a century later (Garner *et al.* 1994). The exceptional preservation in the waterlogged depths of Copa Hill in central Wales (Timberlake 2003b) have led to the recovery of even more wooden and organic mining paraphernalia including cut round wood, for fire setting and withies for hafting. A unique artefact from the site of Copa Hill is a launder made from a solid piece of alder (Timberlake 2003b).

The recovery of antler and bone tools from a number of mining contexts has again led to the dating of sites to the earlier Bronze Age (Barnatt and Thomas 1998; Lewis 1994; O'Brien 2004). These appear to have been used as picks, chisels, and wedges to separate and pry out loose material (Barnatt and Thomas 1998; Craddock 1995; Lewis 1994). The faunal assemblage recovered at the Great Orme is particularly rich and dominated by the long bones of cattle and to a lesser degree pigs (James 2011; Lewis 1994). The assemblage is comprised of long bones, ribs and fragments that were originally interpreted as the remains of underground meals; however more recent analysis has led to the conclusion that the heavily utilized bones were in fact tools well suited to the dolomitized geology of the Great Orme (James 2011; Lewis 1990b; 1994).

It is the ubiquitous hammer stones that appear to have been synonymous with pre-iron mines and mining (Craddock 1989; Craddock 1995). Hammer stones are usually well rounded, water worn cobbles and can be identified by distinctive use wear patterns indicative of a battering action, with the heaviest wear represented by heavy damage and the removal of spalls from the tools (O'Brien 2004; Timberlake 2001b; Timberlake and Prag 2005). The need for hammer stones to be harder and more durable than the host rock of the mines also means they tend to stand apart from local stone and materials such as quartzite (Guilbert 1994a; Guilbert 1994b; Pickin 1999; Pickin and Worthington 1989; Timberlake and Craddock 2003), andesite (Timberlake and Prag 2005), Dolerite and Basalt (Lewis 1990b; Lewis 1994) were likely chosen for their durability and in many cases may have been transported from some distance to the mines (Lewis 1990b; 1994; Timberlake and Craddock 2003). However, evidence for the use of local material as hammer stones can be seen in the use of gritstone and limestone cobbles at Ecton (Guilbert 1994a; Pickin 1999) and a number of locally sourced sandstones and greywacke cobbles reported from Alderley Edge (Timberlake and Prag 2005).

The greater majority of the hammer stones from Alderley Edge have been extensively modified with a pecked groove around their lateral axis, presumably to aid in hafting (Gale 1989; Gale 1990; Pickin 1990; Timberlake and Prag 2005). Extreme examples have an additional pecked groove extending halfway around their longitudinal axis from the lateral facet (Gale 1990; Pickin 1990; Timberlake and Prag 2005). The modification of hammer stones has not been as extensively seen at other mining sites. Typological classifications of stone hammers have arisen based on levels of modification and/or types and levels of use wear (c.f. Gale 1990; Pickin 1990; Thorburn 1990).

To date no bronze objects have been recovered from a mining context save for three metal artefacts recovered from one site, the Great Orme in North Wales. Two bronze chisels and an as yet unidentified globular object, often described as a lost adornment from a larger composite tool, were recovered from a secure underground context within the old workings on the Orme (Lewis 1990b). The longstanding absence of bronze at Bronze Age mines has been interpreted as a general prohibition on the use of metal tools in mining contexts. The material and tools made from it may have been seen as too rare or valuable to be used in mining contexts. However, the analysis of preserved wooden objects from Copa Hill (Timberlake 2003b) and Mount Gabriel, in Ireland (O'Brien 1994) has proffered evidence for the presence of, or at least the use of bronze or copper tools in conjunction with mining activity, in the preserved tool marks. A whetstone found at Mount Gabriel, fashioned from the local sandstone, showed evidence of wear consistent with the sharpening of metal blades (O'Brien 1994) and further re-enforces the presence of metal tools at the mines. An alternative interpretation is that there were other more suitable materials used in the mineral extraction, but metal tools were used for other activities at or near the mine and, owing to their value, never left behind.

Experimental archaeology has shown the effectiveness of the Bronze Age tool kit in the extraction of copper ores including the hafting of hammer stones (Craddock 1990a). Fire setting and mining experiments conducted at Copa Hill (Timberlake 1990d) and the Great Orme (Lewis 1990a) have demonstrated the practicality of fire setting combined with bone or antler and stone tools. Further experimental work at the Great Orme has shown that the well-utilized bone assemblage was more than sufficient to extract the ore from the heavily weathered, dolomitized limestone in which it was found (James 2011; Lewis 1994). While experimental fire setting has shown the practicality of this technique it has also underlined the skill involved; the necessity of understanding the surrounding geology; and the importance of an adequate supply of materials, namely fuels (Crew 1990; Lewis 1990a; O'Brien 1994; Timberlake 1990d).

3.3.3. Mineral Choice and Geology

Mineral exploitation during the first millennium of metal use in Britain was not limited to a single type of copper bearing mineral, nor was its distribution defined by a uniform geological setting, but can be seen to exploit a number of available minerals across the diverse geology of Britain. As mentioned in chapter two the majority of known copper deposits that were exploited in the Early Bronze Age would produce a relatively pure copper metal (Ixer and Budd 1998); however understanding the kinds of minerals that the earliest metallurgists were exploiting is important in the context of early metal production. This can be difficult to estimate given that the nature of mining itself removes the very evidence we seek to identify (Rohl and Needham 1998). Subsequent mining and other activities have also conspired to obscure the earlier evidence and further complicate the task. Many of the mineral rich deposits at Bronze Age mining sites were also developed in the post-medieval period (c.f. Carlon 1979; Jones *et al.* 2004; O'Brien 2000; Porter 2004; Rowlands 1966). While this activity has provided a wealth of knowledge regarding the minerals available at these sites, it has obscured the evidence of prehistoric mining and the kinds of minerals chosen by the early miners.

There is, however, enough remaining evidence at a number of sites to at least begin to discuss mineral choices and the types of host rock with which Bronze Age miners had to contend. The earliest metal objects in Britain are composed of Northover's metal type A, which comes from the smelting of the poly-metallic ore, tennantite, such as that mined at Ross Island in County Kerry, Ireland. This type of ore is similar to several known fahlerz ores on the Iberian Peninsula (Almagro-Gorbea 1995; O'Brien 1995; 1999; 2004), but to date has not been identified in Bronze Age mining contexts in Britain. Therefore, only the tennantite mined at Ross Island could have formed copper metal with significant quantities of other elements to create metal type A. The initial use of this arsenic rich copper ore may represent a particular or pre-existing knowledge of the properties of this type of ore (O'Brien 1999; 2004).

There is clear evidence for the extraction of the primary sulphide ore chalcopyrite at, in particular Copa Hill, in Central Wales (Timberlake 2003b). This is found alongside galena; however, the lead ore appears to have been discarded at the site and in the adjacent tips (Timberlake 2003b). Chalcopyrite is seen at the majority of the mines identified in Mid Wales (Ixer 2003; Ixer and Budd 1998; Jones and Frost 2004; Timberlake 1990c; 1995b; 1996b; 1998; 2009). Although chalcopyrite was extracted and even processed at Copa Hill (see section 3.4 below)(Timberlake 2003b) the primary investigator has acknowledged the possibility that following the initial treatment of the chalcopyrite it may have been washed or further processed in some manner with only the oxidised copper mineral collected and taken to be smelted at another location (Timberlake 2010). The specialised system of launders observed at this site may have served in the further separation of lead, primary, and secondary copper minerals (Timberlake 2010). Carbonate minerals such as malachite and goethite were seen in weathered sections of samples taken from the site (Timberlake 2003b). Other sulphide minerals identified at Copa Hill, include definite, covalline and yarrowite though these were found in weathered samples taken from spoil mounds and are more likely to represent post depositional weathering than mined minerals (Ixer 2003). The juxtaposition between copper and lead ores is not limited to Copa Hill as several dated and suspected early mines in Mid Wales were later mined for lead not copper, including Nant Yr Eria (Jones and Frost 2004; Timberlake 1990c). Ecton Hill in North Staffordshire was also mined for both lead and copper from the 17th century to the late 19th century (Porter 2004; Robey and Porter 1972).

The majority of the Bronze Age copper mines in Wales are found in a Silurian sedimentary geology of mixed mudstone, siltstone, and sandstone, generally finer grained that that found at Cwmystwyth (Jenkins 1995; Jones *et al.* 2004). The mines of the Great Orme headland are an exception. The Great Orme is a limestone massive that projects into the Irish sea (Lewis 1994; Wager 2001b). The limestone surrounding the mineral deposits close to the surface is highly weathered and has been heavily dolomitised (Lewis 1994). Chalcopyrite is the primary ore at the Great Orme mines in the Pyllau Valley (Dutton 1990). However, the heavily weathered limestone also hosted the secondary ores azurite and in particular, malachite in significant quantities and the evidence suggests that this was the mineral exploited during the Bronze Age (Dutton 1990; Lewis 1990b; Lewis 1994).

Alderley Edge hosts significant accumulations of secondary minerals. Malachite and azurite were both mined at this site (Carlon 1979; Ixer 1994; Timberlake and Prag 2005). Alderley Edge, like and Mount Gabriel in Southwest Ireland, is situated in a Devonian sedimentary formation known as the Old Red Sandstone (O'Brien 1994; Timberlake and Prag 2005). However, while the stringers of malachite found at Mount Gabriel were not deemed economically viable by later mining companies (O'Brien 1994) the mineral deposits of Alderley Edge were periodically mined in later history (Carlon 1979). The ores from both of these sites was a sandy rock that was cemented with copper mineral, usually malachite (Carlon 1979; Ixer 1994).

Native copper and other minor minerals have been reported and/or observed at a number of the mines including Copa Hill (Ixer 2003), the Great Orme (Lewis 1990b), and Ecton (Braithwaite 1991), but it is not possible to know what percentage of these minerals may have been available in prehistory and to what extent it contributed to the available copper in the earliest Bronze Age. Contrary to previous claims that that Bronze Age miners in Britain would only exploit simple and easily smelted minerals, such as the readily identifiable oxides and other secondary ores, there is clear evidence from Copa Hill that chalcopyrite was extracted from the mineral veins, although this may have only been a matter of convenience to gain more carbonate ores through careful processing of the extracted material. The recognition and use of poly-metallic ores from the outset of the Bronze Age demonstrates a working knowledge of their properties and the knowledge and skill to reduce them to an arsenical alloy. The choice of ores widened through the Early Bronze Age and malachite and other secondary ores were exploited at mines across England and Wales (Ixer 2003; Ixer and Budd 1998; 2003a; Timberlake 2003b; Timberlake and Prag 2005).

3.4. Beneficiation

Beneficiation is a term that encompasses the processes enacted on the ore after it is mined in order to separate as much of the mineral as possible from the gangue, or waste rock. It serves to concentrate the copper content of the material to be smelted and reduce the waste material introduced to the crucible or furnace (Doonan 1994). This is accomplished by crushing the extracted ore and hand sorting the fragments of mineral from the sterile rock. This practice can be directly observed at very few of the known mining sites in Britain (Timberlake 2003a; Timberlake 2003b).

The best example of the further processing of ores has already been noted at Copa Hill. Here, a working surface in the entrance to the opencast was found, covered in finely crushed material (Timberlake 2003b). A small pile of hand-sorted chalcopyrite was also found in this work space (Timberlake 2003b); however, as this material was left behind by the Bronze Age miners, it may not have been their target mineral at the site. The presence of finely crushed material, along with finely crushed and well sorted spoil, is the primary indicator for the careful processing of extracted material to ensure the collection of as much viable ore as possible. As seen from the excavation of mining spoil at mines 3 and 4 on Mount Gabriel, (O'Brien 1994) finely crushed waste material within the tip and a notable absence of any copper mineral is indicative of hand crushing and sorting.

The patterns of use wear on hammer stones from other mining sites also bear witness to the beneficiation of ore within the mining context. The analysis of a number of stone tools from the Great Orme (Lewis 1994) and Ecton (Guilbert 1994a; Pickin 1999) have demonstrated that they were used in a much lighter crushing and/or grinding fashion. This is similar to the use wear on tools from Copa Hill, where the tools are recovered from a known ore-processing context, and supports the interpretation that at least the initial beneficiation of ores was taking place at, or in direct association with the mine at these sites. Unfortunately, these tools were predominantly recovered from uncertain contexts. Several of the hammer stones collected at Ecton were found in the mining spoil of the much later Dutchman's level (Guilbert 1994a). The remainder of the stone tools relating to beneficiation at Ecton were part of the Bateman collection, which is curated at the Weston park museum in Sheffield (Ford 1994; Guilbert 1994b; Pickin 1999). The only clue to their provenance is a handwritten note that declares: "Found in an ancient copper mine at Ecton June 1855" (Bateman as quoted in Guilbert 1994b)

Recent excavation at Ecton have added to this body of evidence and provided some more secure contexts for the recovery of material from this site. A number of the tools found at the Great Orme were recovered beneath more recent industrial spoil during the excavation of surface features and come from secondary or mixed contexts (Dutton and Fasham 1994; Lewis 1994). The lack of secure context for these tools does not invalidate the evidence for the initial beneficiation of ores at the mining site, but does hamper the specific identification of activity areas at these sites.

Beneficiation may also include washing the ore in order to facilitate the identification and collection of mineral. Experimental beneficiation has shown the efficiency of the process is increased when water is available to wash the ore during what has been shown to be a dusty process (Doonan 1994). Grinding the ore may result in a finely crushed material, which presents difficulty in hand sorting and may have led to gravity separation (Craddock 1995). Gravity separation is a method of separating fine-grained material by immersing it in water. The lighter gangue particles become suspended in the water and are washed away leaving behind the heavier mineral to be collected (Craddock 1995). There is no direct evidence for the use of gravity separation in Britain in the Bronze Age; however a direct association between ore processing and water is observable.

The site of the opencast at Copa Hill did not need an artificial water source and there is plenty of evidence that drainage posed a problem at the mine (Timberlake 2003b). The use of the alder wood launder provided one solution to the issue of water collection within the mine, but may also have been a resource for other activities. The working surface, mentioned above, is located next to the launder (Timberlake 2003b), which would have provided access to a controlled water source. Timberlake (2010) has suggested that the finely crushed chalcopyrite seen on the working surface at Copa Hill was the product of a process of beneficiation that included washing the ore in order to increase the selection and recovery of oxidized minerals, rather than the purposeful selection of the primary ore, which is harder to smelt.

Figure 3. 4 Distribution of Bronze Age ore processing sites

Further evidence for the association of beneficiation with a source of water comes from the Great Orme headland in north Wales. Evidence for Bronze Age mineral separation has been found at Ffynnon Rufeinig, a water source just under 1km from the Pyllau Valley and the Bronze Age mines of the Great Orme (Ottaway and Wager 2000; Wager 1997; 2001a). The site is sealed by a primary deposit composed of a mound of well sorted dolomitic limestone fragments with nodules of malachite and azurite in close context with a possible hammer stone spall and green stained bones (Wager 2001a). The radiocarbon dating of two of the bones places the site within the Early Bronze Age (1880 – 1680 BC calibrated to 1 sigma) (Wager 2001a). The site at Ffynnon Rufeinig is the only dated ore-processing site in Britain that has been found away from the primary mining context.

The successful separation of mineral from gangue is a simple skill. The ability to differentiate the mineral from the gangue and separate them by hand is easily learned; however more advanced techniques, such as gravity separation, require additional practice. Experimental beneficiation conducted by Pitman (pers. com.) has revealed the varying success experienced by individuals with different operational and mineralogical knowledge. As with mining the separation of mineral from gangue does not represent a wholly new activity, but has parallels in the processing of domestic crops and in particular grains (Giles 2007; Hingley 1997). Following the beneficiation of the ore it would need to be smelted in order to create metal; however the processed ore may have itself been an accepted material for exchange. Evidence for the exchange or transport of processed, but unsmelted ore comes from the Kargaly region of the southern Urals, where it was apparently exchanged for animals, (Chernych 1992; Ottaway and Roberts 2008), Klingberg in Austria (Shennan 1998; Shennan 1999) and from Chrysokamino, on Crete, where Cycladic ores from Kythnos were smelted (Betancourt 2007). The high concentration of animal bones recovered from mines of the Great Orme (Lewis 1994) may also allude to the exchange of processed copper ore.

3.5. Smelting

Unlike lithic production, the making of metal is a transformative process that relies on the high temperature alteration of one material into another. In so doing it requires a range of materials and tasks coming together in co-operation. Alongside the existing evidence for Bronze Age copper smelting from Britain, this section will present a range of additional information. Because of the paucity of existent evidence, this section will highlight the means through which copper minerals could be smelted. The possible transformation pathways show the technical needs in order to produce metallic copper from different types of ore while the materials present different means of satisfying the technical requirements. This section will also draw on experimental approaches that have attempted to recreate the perceived conditions of copper smelting in the British Isles during the Early Bronze Age . Copper is not the only outcome of a successful smelt and this section will also begin to examine slag as a material.

Unlike other pyrotechnical practices from this period copper smelting required constant attention. The firing of ceramics and to some degree certain methods of food preparation could be set and left for periods unattended. However there was a proximity demand in the metallurgical conversion of ore to metal. The furnace could not be left unattended while conversion was in progress, but had to be attended, making the process highly performative. It involved the intimate connection of smelter with the materials and could be considered to parallel flint knapping or the forming of a ceramic vessel. Smelting involved the skilled coordination of fire, air [atmosphere], fuel, ore, and, if needed, flux in a reaction that may have carried a greater sense of drama.

3.5.1. Transformation Pathways

A relatively pure ore, such as the oxide cuprite, can be reduced to metal by melting the ore in a reducing atmosphere, created by using charcoal fuel (Tylecote 1986; Tylecote 1987; Zwicker *et al.* 1992). The oxygen in the ore becomes separated when the fire is starved of oxygen, or given a surplus of carbon. It reacts with the carbon monoxide present in the surrounding atmosphere to form the more stable carbon-dioxide, releasing the copper metal [$Cu_2O + CO = 2\ Cu$ and CO_2] (Hanks and Doonan 2009)

When different and more complex ores are used different pathways become necessary. Chalcopyrite is a sulphide ore and although its presence has been noted at a number of Bronze Age mining sites has been noted (Ixer 2003; Ixer and Budd 1998) its exploitation during the Bronze Age in Britain has been questioned. While there is clear evidence for the extraction of this mineral during the Early Bronze Age , there is no such evidence for the smelting of chalcopyrite, or other complex sulphide copper ores, during the first millennium of metal production in Britain. Primary sulphide ores were, however, mined and smelted in other parts of the Bronze Age world (Doonan and Day 2007; Tylecote 1987; Zwicker *et al.* 1992). Therefore the potential transformation pathways of this mineral are given here as an example of the processes that more complex ores would need to be put through in order to produce copper metal.

Hanks and Doonan (2009) provide three possible multi-stage pathways through which this ore can be smelted. The ore can first be oxidised by roasting it in an open or oxidizing atmosphere (Craddock 1989; Craddock 1995; Hanks and Doonan 2009). This removes the sulphur and creates what is in essence a synthetic oxide ore [$CuFeS_2 + 3\ O_2 + C = CuO + FeO + 2SO_2 + CO_2$]. Roasting the sulphide ore does not require the same high temperatures as smelting as the goal is not to melt the ore, but to burn off the sulphur. It is then possible to smelt the copper oxide using the same reaction as above [$CuO + CO = Cu + CO_2$] (Hanks and Doonan 2009)

The second path uses a partially roasted ore, so that some of the sulphur is retained [$2CuFeS_2 + 3O_2 = CuO + FeO + CuS + FeS + 2SO_2$]. The sulphide and oxide ores are then co-smelted [$2CuO + CuS = 3Cu + SO_2$][$FeS + CuO = CuS + FeO$] with any remaining copper sulphide reprocessed (Hanks and Doonan 2009; Rostoker *et al.* 1989). The atmosphere in a co-smelt is self-regulating due to the presence of both oxygen and sulphur (Rostoker *et al.* 1989).

In the third pathway the sulphide ores are smelted without any roasting. Instead this pathway produces copper matte, a metallic mixture of copper iron and sulphur [$2CuFeS_2$ + Heat = CuFeS + S][CuFeS + Heat = CuS + FeS (matte) + FeO(slag)] (Hanks and Doonan 2009). The matte can then either be passed through one of the roasting methods above and smelted in an appropriate reducing or oxidizing atmosphere or it can be converted (Hanks and Doonan 2009). The bond between the copper and sulphur is stronger than that between iron and sulphur therefore the iron will oxidize and form a slag leaving the copper sulphide [CuS + 3FeS + 5O2 = CuS + Fe_3O_4 + $3SO_2$] (Hanks and Doonan 2009). Once all of the iron has been slagged off, the copper is converted in an oxidizing atmosphere [CuS +O_2 = Cu + SO_2] (after Hanks and Doonan 2009).

These chemical pathways are pre-defined and can therefore sometimes be used to define categories of practice. However they are based on chemical processes that have been observed in modern continuous steady state conversion processes. Ancient practices need not have been so tightly defined or dependent on a single mineral and may have had changeable circumstances. Rostoker et al. (1989) have proposed a smelting process based on less restricted mineral choice. This co-smelting technique would have used both sulphide and oxide ores, creating a self-regulating atmosphere that may have meant the successful conversion of ore to metal under much broader or variable conditions (Rostoker *et al.* 1989).

3.5.2. Materials

The near absence of archaeological evidence in Britain for copper smelting in the Bronze Age presents a puzzle (c.f. Craddock 1990b) with a number of experimental approaches attempting to reproduce a non-slagging or low slag method of copper reduction (Budd 1993; Coghlan 1939; Craddock 1989; Craddock 1990b; Craddock and Timberlake 2004; Timberlake 2005; Tylecote and Merkel 1992). However the absence of slag deposits dating to the Early Bronze Age is not the only missing evidence. There is still no presence in the British archaeological record of smelting structures, such as a furnace, or other key elements, such as smelting crucibles or tuyères, to facilitate this process. Nor is the absence of evidence restricted to the Early Bronze Age . The inference of a non-slagging method of smelting was originally predicated on the low iron content of Early Bronze Age metalwork in Britain (Craddock and Meeks 1987) and although there is even less slag dating to later Bronze Age contexts in Britain, much of the metal in circulation by this time may have been imported from the chalcopyrite based copper production centres in the European Alpine zone. As a smelt is a reaction between copper ore, fuel, oxygen and possibly a flux within a controlled space, it can require the input of a number of potential materials in order to be successful.

Chief among the material requirements of copper smelting is the need to contain the reaction and control the internal atmosphere. The containing structure can be as simple as hollow in the ground, which may or may not have been lined with clay, a crucible set within a hearth, or may make use of far more complex furnace structures (Craddock 1995). Crucible and furnaces have to be constructed of heat resistant materials, which in the Bronze Age were limited clays heavily tempered with sand and possibly organics (Craddock 1995). The use of both sand and organic tempers have been observed in ceramics dating to the Bronze Age in Britain and Ireland, including some crucibles and casting moulds (Liversage 1968; Tylecote 1986). Hearths or furnaces may also have been partially constructed in stone with robust clay linings (Tylecote 1987).

Part of the purpose of the structure is to be able to control the airflow and thus the atmosphere (Tylecote 1986). Smelting and melting copper requires high temperatures and a reasonable draught was needed to reach them. The use of natural draughts has been proposed (Jackson 1980) and may have been one motivation for the location of smelting hearths (c.f. Catapotis 2007), but in the absence of a strong steady wind, artificial airflow could be introduced through a blow pipe or bellows and tuyère (Craddock 1995; Ottaway and Roberts 2008; Tylecote 1986). Bellows would possibly have been made of mostly organic material and thus not likely to survive, although examples of limestone and clay bellows are known from a number of settlement sites in the near east (Davey 1979). The tuyère would have had to endure the high temperatures inside the hearth and would have been made from heavily tempered clay very similar to a crucible, mould or a furnace (Tylecote 1987).

The fuel is another important material both for the creation of the necessary temperatures and for the atmosphere. Experimental research has shown the utility of charcoal as a fuel supply (Craddock 2001; Timberlake 2005), but wood may also have been used. As a fuel, charcoal introduces carbon into the hearth or furnace and could have been a significant material in the creation of a reducing atmosphere and may have been crucial in reaching the necessary temperatures (Craddock 2001; Ottaway and Roberts 2008; Tylecote 1986)

In some cases a successful smelt may have depended on the addition of another material or a flux. A flux is a material that is introduced to the smelt in order to facilitate the separation of metal from the other elements found in the ore by forming slag (Bachmann 1982). Different ores may have needed different fluxes and some ores may even have been self-fluxing. Self-fluxing ores are those where the gangue material and the copper minerals have a gross chemical composition that facilitates the formation of both copper metal and a slag with no additional input (Bachmann 1982). In other cases the appropriate flux would depend on the composition of the copper ore. By adding an appropriate measure of clean sand to an iron rich ore, a viscous slag would be formed by the melting silica drawing off the iron oxide that was in solution with the copper, leaving copper metal (Bachmann 1982). Adding iron oxide to a silica rich ore would have the same result. According to Bachman (1982) the choice of fluxes available in prehistory were limited to the gangue available with the ores, iron and manganese oxides, lime, silica and possibly fluorspar. An appropriate flux allows the associated gangue minerals to be more easily separated from the desired copper charge. In many cases this results in a lower melting point and a lower viscosity (Bachmann 1982); however, in the case of matte conversion the addition of a silica flux is essential in the chemical separation of the iron oxide and was not necessarily aimed at controlling the physical or mechanical properties of the slag (Hanks and Doonan 2009).

3.5.3. Evidence of Copper Smelting

The most common evidence of production is the waste material left behind whilst the finished product has been taken by the producers. This is true of lithic production, where the debitage is left at the site of production while tools are taken away and used, and it is true of metallurgical production. Because the desired result of copper smelting is the copper metal archaeologists have expected to find accumulations of slag, possibly in association with broken fragments of crucible and tuyère or furnace bases, indicating the site where smelting took place in the Bronze Age, the finished metal having been taken by the producers (Bachmann 1982). Many sites in Europe and beyond have been identified based on the presence of large volumes of often, though not exclusively, crushed slag (Bachmann 1982; Bassiakos and Philaniotou 2007; Doonan 2008; Kassianidou 1999). However, similar evidence has yet to be identified in Britain.

Early metals were precious with a large effort put into their extraction. The careful and meticulous recovery of metallic copper from smelting sites has been attested to by numerous excavations at Bronze Age sites across Europe and the Near East where the deposits are dominated by finely crushed slag no more than a couple of centimetres in size (Betancourt 2007; Catapotis and Bassiakos 2007). This has been interpreted as a conscious effort to recover as much metallic copper from each smelting event as possible by crushing the slag and removing copper prills that have formed within. This is not to say that Early Bronze Age smelters were only capable of producing prills, but that every effort was expended in recovering as much copper as was possible because no slag is entirely free of metallic inclusions and copper metal often appears as droplets or prills varying in size from microscopic to several millimetres in size within the slag (Bachmann 1982).

It is the slag that more closely relates to the ores smelted (Bachmann 1982), rather than the metal, which, while it can contain elements present in the ore, is often subject to further processing alloying and mixing. The slag acts as a collector for impurities in the ores as well as the remaining gangue, furnace or crucible lining and charcoal (Bachmann 1982). Thus the slag composition is influenced by the ore and gangue, additional fluxes and the materials used in the furnace [or crucible] construction that come into contact with the charge such as furnace lining or tuyères and the fuel ash. The heat, airflow and duration of the smelt may also affect the formation of the slag (Bachmann 1982).

According to Bachman (1982), the transformation of ore to metal without forming a slag requires the careful control of the materials and a closely regulated temperature and atmosphere only possible in a controlled setting. However, The purer the ore, the less slag will be produced (Bachmann 1982). Craddock (1989; 1995) has proposed that the careful processing of ore would concentrate the copper content and severely reduce the gangue, thus producing less slag. Experimental attempts have succeeded in producing small prills of copper metal in a controlled smelting process that produced little to no recognizable slag (Craddock and Timberlake 2004; O'Brien 2004; Pollard *et al.* 1990; Pollard *et al.* 1991; Timberlake 2005).

To date, potential evidence for Early Bronze Age copper smelting has been recovered from only one Bronze Age in Britain, the site of Pentrwyn on the Great Orme (see figure 3.1). A small 'v' shaped feature is visible on the eastern side of the headland, in the cutting above the modern road that leads around the coast and up onto the headland. The site was identified during a rescue dig by the Gwynedd Archaeological Trust in advance of the widening of the road and subsequently dated to 1675-1500 cal BC (Chapman 1997; Jones 1999). Roughly 500g of slag like material was recovered from within the feature, which has been interpreted as a hearth (Chapman 1997). Microscopic and chemical analysis of this material has confirmed its connection with copper metallurgy (Eldridge and Doonan 2010; Salter unpublished report).

Figure 3. 5 Distribution of known and possible Bronze Age smelting sites

Figure 3. 6 Early Bronze Age smelting feature at Pentrwyn, Great Orme headland

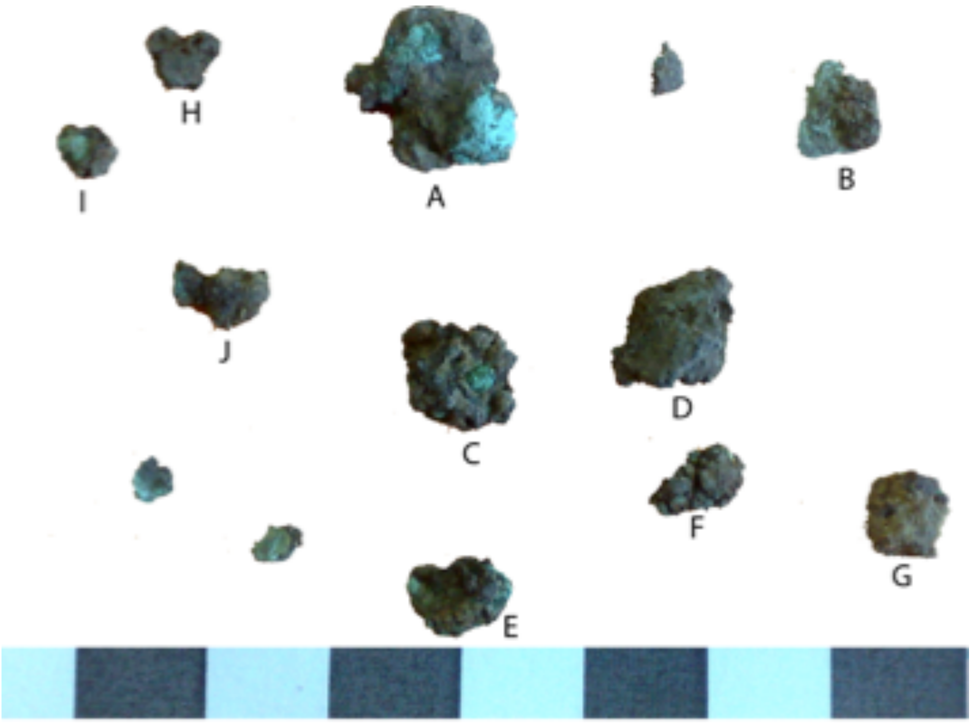

Figure 3. 7 Sample of slag like material from infill of smelting feature at Pentrwyn

ferrous copper and lead slags, and magnetite [Fe_3O_4] (Bachmann 1982). Hematite [Fe_2O_3] is generally only present in slag produced in highly oxidizing conditions (Bachmann 1982). Antimonies or arsenides are only found in slag where The slag-like material recovered from Pentrwyn is similar to a single plano-convex piece of slag-like material, weighing 500g, that was found associated with a fragment of Bronze Age pottery and fragments of a grinding stone at Ballydowny in County Kerry, Ireland (Kiely and O'Callaghan 2009) This deposit has also been dated to the Early Bronze Age [2030-1870 BC] (Fairburn 2009), coeval with the final phase of mining activity at Ross Island (O'Brien 2004).

Slags are, according to Bachmann (1982), basically silicates. They are in essence man-made compounds that hold the clues to the metal making process. Common mineral compounds found in copper smelting slag include wüstite [FeO], which is common in fahlerz ores were smelted (Bachmann 1982), such as Ross Island (O'Brien 2004), while sulphides are expected to appear in slags only if sulphide ores were being smelted. In the absence of this material it remains difficult to definitively discern what types of minerals were being smelted in Britain during the first millennium or metal production. The general absence of evidence for copper smelting continues through the Bronze Age.

Analysis of the Early Bronze Age slags from Pentrwyn, in North Wales, indicates that it, like the material recovered from Ballydowny, is iron rich and surprisingly low in silica (Salter unpublished report). A similar composition was found in slag like material from a possibly later Bronze Age component on Dalkey Island, County Dublin in Ireland (liversage 1968). The Bronze Age slag-like material from Pentrwyn shows higher levels of calcium and iron oxides [CaO-FeO-Fe_2O] with only small pools of silica (Salter unpublished report) which mirrors the compositional range of more modern copper smelting processes (Davenport *et al.* 2002). As expected in copper smelting, metallic copper was present in the slag (Eldridge and Doonan 2010; Liversage 1968; Salter unpublished report).

The use of the fahlore tennantite in Ireland from the very early stages of metal production in the Bronze Age indicates that the earliest metallurgists in the British

Isles were able to reduce this type of complex poly-metallic ore. While, to date, evidence for the extraction of tennantite, or other fahlores, is found only at Ross Island (O'Brien 2004), there is clear evidence for the extraction and initial processing of chalcopyrite at Copa Hill (Timberlake 2003b). Chalcopyrite is also found in mining sites across Britain (Ixer 2003; Ixer and Budd 1998). However, there is no other clear evidence for the extraction of chalcopyrite and Timberlake (2010) has suggested that the evidence at Copa Hill may reflect the processing of this ore to garner additional oxidized ores from the processed sulphide ore. The near total absence of evidence for smelting or slag from Bronze Age contexts in Britain presents additional complications in identifying this process and the materials on which it was fed. It is important to note that while slag is often regarded as a by-product and waste material it is a material that was often made by the smelter. Slag is not simply a by-product of the smelting process, but may have been intentionally formed, or avoided, utilising specific recipes intended to aid the production of copper by allowing the gangue minerals and copper to separate more easily. In essence, by creating a good slag, the smelter could be sure of creating a good metal (Pitman, pers. comm.), although the intention behind the creation or avoidance of slag may have been culturally constrained and could necessitated specific treatment of this material if produced. This is an idea that will be picked up in the discussion of this thesis.

3.6. The Archaeology of Metallurgical Sites in Britain

There is a tendency to see the European Bronze Age as a historically unique development with new means and techniques for resource acquisition developed in response to new materials. Bronze Age societies and their activities are therefore seen as distinct and distanced from similar evidence available in the Neolithic period (Kienlin and Stöllner 2009). However, mining was neither a new nor a unique task developed in response to the demand for metals in later prehistory. Neolithic miners, in search of lithic raw materials, developed intricate mining and quarrying strategies in response to the negotiated needs of their society (Barber *et al.* 1999; Claris and Quartermaine 1989). Other aspects of the metallurgical *chaîne opératoire* also have pre-existing parallels.

The practice of beneficiation might seem wholly unfamiliar to someone with no previous metallurgical experience. However, the tools, skill, and especially the bodily postures used in the processing of ores most likely reference practices in other arenas of social life. As such they are given meaning through familiarity with existing practices. In this manner the crushing and separation of ores has immediate parallels in the preparation of grains (Giles 2007; Hingley 1997) and may be draw on comparable symbolic schemes. The identification, assessment, and retrieval of minerals parallels lithic production with similar implications (Edmonds 1995). Therefore, early mining and mineral processing should be considered in light of both the context and understanding of existing Neolithic practices.

Neolithic flint mines and quarries have received widespread attention in archaeological discourse, impacting perceptions of social organization and revolutionizing understanding of Neolithic production and exchange (c.f. Barber *et al.* 1999; Bradley 1984; Bradley and Edmonds 1993; Cummins 1979; Gardiner 1990). By comparison the Bronze Age copper mines remain on the periphery of discussions within the discipline. Nor have archaeometallurgists been quick to explore the potential of these sites beyond cataloguing the types of metal that could be produced from the ore bodies by elemental impurity and / or lead isotopes (Ixer 1999; Ixer and Budd 1998; Northover 1989; Rohl 1995; Rohl and Needham 1998).

Flint mines were perhaps more readily recognized due to the nature of material culture present at the sites allowing for the recognition of the prehistoric habitation and a range of associated activity that seems to have taken place at the sites. Copper mines, on the other hand are remarkably sterile of identifiable Bronze Age material. As early as 1744 antiquarians suggested that the 'owld man' workings and stone tools encountered by miners at several copper mines were left by 'pre-iron using people' (Sykes 1790 reproduced in Briggs 1976; Morris 1744 as in Timberlake 2001a); however, in the absence of material culture the copper mines they were largely heralded as roman or Romano British (Evans 1872;

Stanley 1850; Stanley 1873). As the discipline of archaeology developed the recognition of Neolithic activity at flint mines resulted in continued interest and evidence garnered from excavations at these sites bolstered new ideas on production, exchange and social organization. However, as the copper mining industry in Britain declined and eventually ceased no new discoveries of older mines or stone tools were reported. Cursory re-investigations of the earliest mining in Wales by Davis (1937; 1938; 1939; 1947; 1948) revealed no additional cultural material and archaeological interest in the un-dateable stone hammers and 'owld man' workings waned. While archaeology has developed a sense of ownership over the flint mines, based in the primacy of archaeological inquiry at the sites, the copper mines have developed into sites of interest for a range of disciplines and interests; mining historians, geologists, industrial archaeologists and cavers have all developed vested interests in former mines and established their own sense of tenure at these sites. With archaeology now beginning to recognize the potential of these sites in Britain we now share their exploration, though rarely the information gathered.

There are now a number of copper mining sites that have been securely dated to the earlier Bronze Age, and even more that are believed to be roughly coeval based on similar material remains and formation processes. Aside from the fortuitous discovery of the Pentrwyn smelting site (Chapman 1997) archaeological survey and investigations relating to metal production have been focused on the extractive sites, as evident in this chapter. This mine-centric approach is due in large part to the amplified visibility of extractive sites, which is based on recurrent Bronze Age activity, and has been augmented by the careful examination of antiquarian and mining records from the 17th to 19th centuries. Exploration of mining sites in England and Wales by the Early Mines Research Group has also added to the corpus of identified mining sites (Timberlake 1992b; 1994; 1998; 2001a; 2002b). However insufficient work has been done to situate most of these sites in an appropriate Early Bronze Age context.

Further survey on the Great Orme has revealed mineral processing in close association with waterways (Ottaway and Wager 2000; Wager 1997; Wager

2001a) and survey at Copa Hill extend to the hillside on which the mines are situated (Jackson 1968; O'Brien 1994; Timberlake 2003b). These were primarily visual surveys that were necessarily biased toward features that are visible at the surface, such as mine workings, the mounds of mining spoil and more recent turbary and farming activities (O'Brien 1994; Timberlake 2003b). However; the archaeological focus remains very much on the copper mines themselves with project goals of many excavations not extending beyond an assessment of, and attempts to date, the earliest activity observed at the site (Timberlake 1990c; 1992a; 1995b; 1996b; 1996c).

As should be apparent through this chapter, one of the key issues in the investigation of early metallurgy is the lack of further research and fieldwork, extending beyond the point of mineral extraction. One of the implicit assumptions inherent in the approaches to Bronze Age metallurgy is that the entire sequence of operations, or metallurgical taskscape will be represented in the immediate hinterland of the mine site as has been observed at Ross Island (O'Brien 2004) and in later Bronze Age sites elsewhere in Europe (Chernych 1992; Jovanovic 1978; Shennan 1998). However, the Bronze Age is not a homogenous period with established settlement and industrial centres. Rather, it can be sub-divided in a number of potentially meaningful ways. For the purposes of this discussion it will be divided into the early and the later Bronze Age. The distinction between these two periods is summarized in the settlement pattern with the later Bronze Age featuring more sedentism and site development that is absent from the Early Bronze Age . The later period is known for structured habitation sites, enclosures, field systems and cremation cemeteries (Barrett 1994b; Barrett and Bradley 1980; Bewley 1994; Cunliffe 1991; Fleming 1988; Fokkens 1997; Malim 2001; Yates 1999; Yates 2001). While these changes undoubtedly originated in the Early Bronze Age (Johnston 2001; Rowlands 1984), very little evidence of permanent settlement has been found for the Early Bronze Age (c.f. Garner 2001; 2007). Mobile populations characterize the earlier period with only the deceased inhabiting a single place within the landscape (Barrett 1994a; Brück 1999; Brück 2000; Kitchen 2001).

With the majority of the mining evidence dating to the Early Bronze Age , the patterns of coeval activities and settlement observed in the archaeological record should inform the investigation of the metallurgical taskscape. A single site focus may not be sufficient to identify the traces of primary metallurgy, which, like the evidence of settlement, may be deposited within the dispersed landscape of a mobile population. Evidence of early metallurgy elsewhere is disarticulated with the various tasks spread across the landscape (Doonan and Day 2007; Rovira 2002). Evidence from these parallel lines of inquiry should be used to inform the investigation of metal making in the landscapes of Britain and Ireland.

The following chapters explore in more detail a single site that will form the case study for this thesis. Drawing heavily on work that has been done at other sites, chapter 4 will examine the history and setting of Ecton Hill in North Staffordshire, the location of both historic and Bronze Age copper mining. Chapter 5 will then outline a methodology for fieldwork, centring on Ecton and expanding into the surrounding landscape, developed in response to the work that has preceded it at the site as well as what has been done in the context of primary copper metallurgy reviewed in this chapter.

4. The Regional Context of, and Evidence for, Bronze Age Mining At Ecton.

4.1. Introduction

Ecton Hill has borne witness to copper mining activity over a period of four millennia, stretching from the Early Bronze Age to the 20th century. It forms the eastern flank of the upper Manifold Valley and a striking geological formation within the limestone plateau of the Peak District National Park. The Peak District is itself a region of diverse landscapes built upon disparate geological foundations with distinct topography and hydrology, supporting a wide range of ecological environments. The diverse environments provide a range of resources and ecological zones from which Bronze Age people could draw. The *chaîne opératoire* of primary copper production requires a combination of resources, from the tools to extract the mineral through to materials for the successful smelting of the ore. It is reasonable to expect these to be distributed across the landscape of the Peak District, with the copper mines representing a fixed point within the metallurgical taskscape (Ingold 1993). Whilst the copper mines are themselves a central focus, this thesis approaches them as a node within an interconnected network of known or possible locales, which extend across the landscape surrounding Ecton Hill and the Manifold Valley.

This chapter will review evidence for mining at Ecton Hill and the impact that more recent activity from the post-medieval period may have had on the remains of Bronze Age. It will also work to establish the context of this activity within a broader inhabited landscape. As mortuary monuments dominate the Bronze Age archaeological remains, evidence of habitation and activity are sparse; nonetheless, drawing on the antiquarian and archaeological work that has taken place within this landscape over the last 150 years, this chapter will outline the landscapes and Late Neolithic / Early Bronze Age setting against which mining and metallurgy at Ecton took place.

4.2. Setting the Scene: the Landscapes of the Peak District

The Peak District is Britain's first National Park, established in 1951 (Barnatt and Smith 1997a). It is an area of rolling pasture and undulating foothills, high moorland and deep valleys. The park is located at the southern end of the Pennine Mountain range, between Sheffield and Manchester. It is also among the most heavily quarried areas in Britain owing to the diverse geology and rich mineral reserves (Brightman and Waddington 2011). The majority of the Peak District is within Derbyshire, but also includes regions of Yorkshire, Cheshire and northern Staffordshire, where Ecton is found (Barnatt and Smith 1997a; Brightman and Waddington 2011; Ordnance Survey 2002). Modern settlement within the Peak District is largely dispersed with only two larger centres found in the Wye Valley: Buxton, which has Roman origins, and the medieval market town of Bakewell. The landscape of the Peak District can be broadly divided into the White Peak and the Dark Peak based on the underlying geology of the region

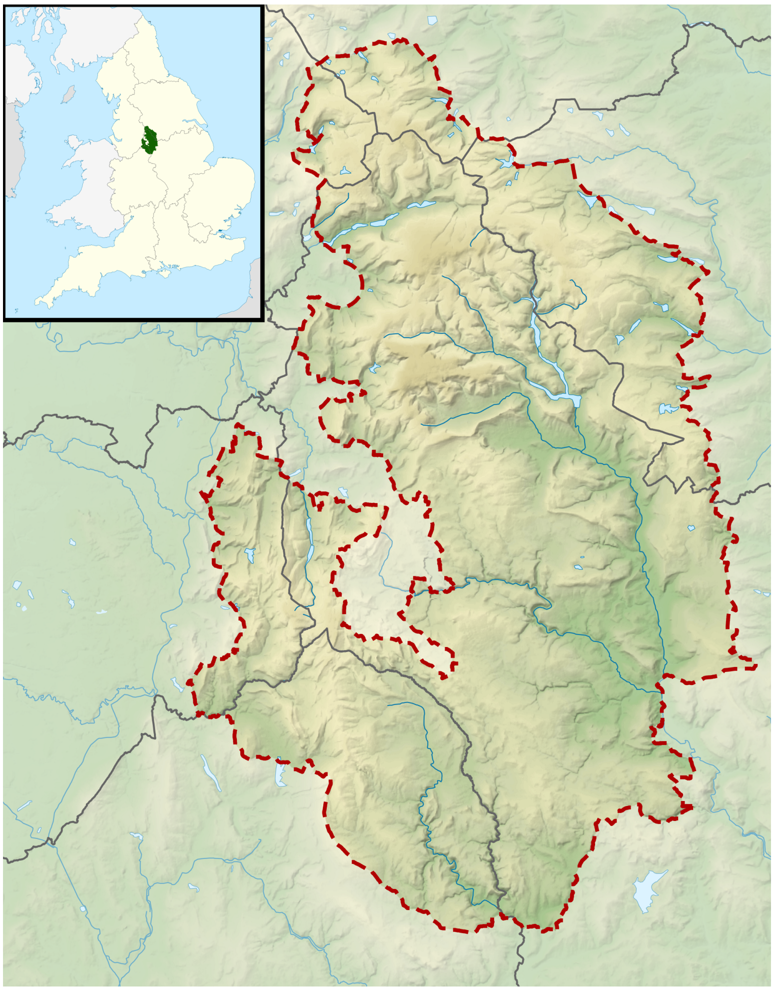

Figure 4. 1 The Peak District National Park

4.2.1. Peak District Geology

The geology of the Peak District developed over a period of 65 million years, between 359 and 299 million years ago in the carboniferous period (Aitkenhead *et al.* 1985; Chrisholm *et al.* 1988; Critchley 1979; Ford 2000). All of the sedimentary rocks that form the bedrock of the Peak District date from this epoch. The coal measures, still visible in pockets on the outer edges of the Peak District, would once have covered even more of the region, but shifting landmasses and erosion removed the deposits millennia ago, exposing the coarse sandstone of the Dark Peak (P.D.N.A. 2008). The gritstone of the Dark Peak, known as Millstone Grit because of its frequent use in milling, and the shale with which it is interleaved are the result of erosion from the Caledonian landmass during the later carboniferous period (Barnatt and Smith 1997a; Smith and Sykes 2009).

Below the sandstone and shale of the Dark Peak, the landscape of the White Peak plateau is unified by its limestone geology, although it comes in different formations (Barnatt and Smith 1997a; P.D.N.A. 2009b; Smith and Sykes 2009). The so-called 'shelf' limestone, most commonly found on the plateau, is thickly bedded and gently dipping, while the 'basin' limestone, found in the southwest of the plateau, is thinner and more strongly folded (Aitkenhead *et al.* 1985; Critchley 1979; Ford 2000). Finally 'reef' limestone, which is less common than the other two formations has formed conical hills or 'reef knolls' around the edge of the plateau, such as Wetton Hill, because it is harder and more resistant to weathering (Critchley 1979; P.D.N.A. 2009b). Following deposition the entire region was subject to movement, which lifted and folded the bedrock. This activity was more severe in the southwest, deeply folding both the millstone grit and the limestone west of the River Dove (Ford 1994; P.D.N.A. 2008; 2009b).

Ecton Hill is another of the 'reef knolls' sitting on the edge of the central plateau. The geology of the Manifold valley and that surrounding Ecton hill is a formation known as Milldale limestone. This is a generally fine-grained limestone with numerous 'mud-mounds' or knoll-reefs (Ford 2000). To the west of the Manifold Valley, Mixon limestone-with-shale overlies the Ecton Limestone. This formation, as the name suggests, has far more shale than the Ecton formation and occasionally includes Onecote Sandstone, a forerunner of the shale and Millstone grit found to the north and east of Ecton (Ford 2000). This area is a junction formation between the White and Dark Peak.

The limestone throughout northeast Staffordshire is folded along a north – south axis (Ford 2000). This is the result of the northwest movement of the neighbouring Derbyshire massif in the late Carboniferous. Many of the deep gorges and caves in the Peak District have more recent origins in the ice ages between 100,000 and 10,000 years ago (Ford 1977; P.D.N.A. 2009b). The movement of the ice sheets across the Peak District carved dales and valleys and melt water coursed down the channels and percolated underground creating fissures and caves in the mildly soluble limestone (Ford 1977; P.D.N.A. 2009b). Many of these features remain in the landscape as dry dales and the river valleys. It is this complex geology that provides the relatively simplistic division between the White and Dark Peak with in the Peak District.

4.2.2. The Dark Peak

The Dark Peak is an upland region with a landscape of high open moor and shallow valleys (Barnatt and Smith 1997a; Dalton et al. 1999). Drainage is poor throughout the Dark Peak and the open moors are mostly covered in blanket peat (P.D.N.A. 2009a; Smith and Sykes 2009). In the north and east this peat can be between two to four metres thick and sometimes even more, while in the southwest it tends to be in more shallow beds between half a metre and two metres deep (P.D.N.A. 2008; 2009a; Phillips *et al.* 1981; Smith and Sykes 2009). This gives the highlands of the Dark Peak a uniform appearance and a feeling of open space that provides panoramic views to distant horizons. It also creates a sense of unrestricted movement through, and access to, vast areas. While the highland landscapes appear smooth, they are, over extended areas, dissected by a network of drainage channels that descend through the bordering slopes and, eventually, down into major rivers in the shallow bottomed valleys below (Dalton *et al.* 1999). The slopes that border the moors drop away steeply, creating a sense of elevation and several major rivers and their tributaries have carved rocky cloughs through this part of the upland landscape which adds to that sense (P.D.N.A. 2008; 2009a). In other areas of the Dark Peak, again particularly in the southwest, enclosed uplands combine a mix of high pasture and former moorland on the high summits and slopes to support pastoral farming (Dalton *et al.* 1999). Coal measures also outcrop in pockets within highlands of the southwest region and were the target of the mining industry through the 18th, 19th, and 20th centuries (P.D.N.A. 2008; Smith and Sykes 2009). Land in this region was mostly enclosed prior to the parliamentary acts of enclosure of the later 18th and early 19th centuries (P.D.N.A. 2008).

Axe Edge, within the Southwest section of the Dark Peak is one of the major watersheds in England and five of the eight major rivers in the Peak District rise here (Barnatt and Smith 1997a). It is the source of the River Dane, which runs southwest through the uplands to enter the Cheshire plain and the Goyt that flows north through the western side of the Dark Peak (Ordnance Survey 2002; Smith and Sykes 2009). Axe Edge is also the source of the River Wye, which flows east through the town of Buxton and crosses the White Peak towards Bakewell, and of the Dove and Manifold, which both flow south through the White Peak (Ordnance Survey 2002; P.D.N.A. 2008). The other major rivers of the Dark Peak are the River Hamps, which also flows out of the Southwest moorland to join the Manifold just south of Ecton (Ordnance Survey 2002), and the Derwent, which flows south out of the northern Dark Peak and along the eastern junction of the White and Dark Peaks (P.D.N.A. 2009a). There are also several brooks and innumerable small unnamed springs across the Dark Peak making for a well-watered landscape.

The shallow valleys below are far less dramatic and soils along the rivers are slightly richer (P.D.N.A. 2009a). The modern focus is still on pastoralist farming and settlement remains dispersed save for the occasional Victorian settlement such as Edale (P.D.N.A. 2009a; Smith and Sykes 2009). In more recent history the poor drainage has led to use of many of the natural shale valleys as reservoirs to provide water to towns and cities in and on the edges of the Peak District (Barnatt and Smith 1997a). The overall effect of the Dark Peak landscape is to create a feeling of openness, even within the wide shallow valleys. Throughout most of the Dark Peak, the horizon is distant and remains constant as you move from place to place, which creates a unified sense of space over large areas where the emphasis is on the foreground, enforcing a sharper concept of place.

The ecology of the Peak District is heavily influenced by the combined geology, hydrology and topography in each zone. It is within the Peak District that some of the most diverse ranges of wildlife species and habitats in England are found (Smith and Sykes 2009). The Dark Peak is home to numerous species of bird including peregrine falcon, grouse and snipe (Anderson and Yalden 1981; Smith and Sykes 2009). On the moors and peat land of the Dark Peak, semi-natural vegetation dominates and, along with the formation of blanket bog, heather and grass moorland grow unrestrained (Anderson and Yalden 1981). Blanket bog has developed over the last 10,000 years on the high moorland with the maximum growth occurring between 8000 and 6500 years ago during a warmer period in prehistory (P.D.N.A. 2009a) although more recently significant degradation and erosion have heavily affected the moorland of the Peak District (Phillips *et al.* 1981). The slightly acidic soils of the uplands make it an unappealing environment for farming and it now is sparsely settled; however, extensive areas of the moor are managed for both wild game and rough grazing (Anderson and Yalden 1981; P.D.N.A. 2008; 2009a). The hills and slopes that flank the high moorland are also subject to peat growth although there are pockets of sheltered semi-natural woodland on many of the slopes, particularly in the southwest (P.D.N.A. 2008; Smith and Sykes 2009). Surviving woodlands are dominated by oak mixed with birch, holly, rowan and hazel, but patches of alder dominated woodland survive along waterways (P.D.N.A. 2008).

4.2.3. The White Peak

The landscapes of the White Peak contrast those of the Dark Peak. It is an area of constantly shifting horizons and visually enclosed or restricted spaces. The White Peak is a carboniferous limestone plateau at the heart of the Peak District (Barnatt and Smith 1997a; Dalton et al. 1988). It is an area that is dominated by undulating farmland and pasture, hills and steep dales (P.D.N.A. 2009b). The farmland is, as the name implies, a settled agricultural landscape. It is generally restricted to deeper loess soils that have collected above streams and rivers and in areas sheltered by hills (Dalton *et al.* 1988). It is this landscape that is the focus for settlement in the Peak District and there is a pattern of nucleated villages, usually with origins in the medieval period, and isolated farmsteads (Barnatt and Smith 1997a; P.D.N.A. 2009b).

The hills of the White Peak, though not as high as those of the northern Dark Peak, can be quite steep (Dalton *et al.* 1988). They are now used predominantly for pastoral farming though quarrying and mining have also had an impact on the landscape (Barnatt 1999a; Barnatt and Smith 1997a; P.D.N.A. 2009b; Porter and Robey 2000). Enclosure on the hillsides followed the prevailing topography, which has led to a number of irregular field systems of both historic and late prehistoric origin (Johnston 2001; Kitchen 2001). Many of the steeply sided smaller dales that cut through the limestone plateau are dry, or host only seasonal streams, while the larger ones are the product of the fast flowing rivers that run through the White Peak (Barnatt and Smith 1997a; Dalton et al. 1988; P.D.N.A. 2009b). The dales of the White Peak often play host to older deciduous woodland and scrub where thickets of ash, oak and hazel grow (P.D.N.A. 2009b).

Figure 4. 2 Landscapes of the White Peak

Movement and visibility in the White Peak present a number of obstacles. The steep dales and valleys, whilst providing a possible corridor and allowing easy movement along the waterways, also impede movement across these same corridors. The hills likewise obstruct visibility in the White Peak. They are features that, unlike the highlands of the Dark Peak, interrupt the landscape and have an immediate impact on a much closer horizon; however, they are also places that, once climbed, provide much wider vistas across spaces within the undulating hills that are otherwise visually secluded. The hills of the White Peak are simultaneously features of an immediate horizon and stand separate from the otherwise accessible landscape. In such a visually restricted landscape concepts of visibility and access could be considered important aspects of negotiating the creation of places and inter-visibility might be a key consideration in the construction of place and use of space.

The White Peak is much dryer than the surrounding Dark Peak with one river rising on the limestone plateau; the Lathkill River, which rises near the town of Monyash and flows east towards the Derwent (Ordnance Survey 2002). The River Wye does cross the White Peak from Buxton in the west to Bakewell in the east before also joining the Derwent (Ordnance Survey 2002). The Manifold and the Dove also cross the White Peak flowing south on either side of Ecton (Ordnance Survey 2002). These rivers flow through dales that are in places so deep they are in fact below the surrounding water table (Barnatt and Smith 1997a). The River Dove, in particular, flows through a series of extremely deep, narrow and steep sided dales that create an enclosed corridor beneath the surrounding plateau. South of Ecton there is even less flowing water outside the major river valleys. The smaller waterways in the White Peak also move through deep valleys and, while not as restrictive as the river valleys, they reinforce the impression of close horizons and spaces delineated by restricted visibility.

The rivers are not only a potential source for a myriad of resources; they also create divisions within the landscape. It would, however, be overly simplistic to think about these as divisions of territory. It is more useful to recognize their possible interpretations, as both barrier and pathway, and their relative connection to the surrounding landscape. Within the Dark Peak the rivers flow through shallow valleys that complement the slopes and highlands. They maintain a connection to their surroundings and are accessible and open, in short they are still very much a part of the wider landscape. On the other hand, rivers on the White Peak delve deeply into the limestone, creating dales that cut through the landscape disconnected from their surroundings along much of their length. The rivers, such as the Dove, feel removed from the general landscape, creating a segregated space. They become not just a barrier to cross, but a separate place altogether and present a way of moving through the rest of the landscape disconnected from the surroundings. In an area of closed horizons and visually defined spaces, the river valleys could serve as pathways between distinct places as easily as barriers between them and, like the hilltops above, become 'other' or liminal spaces.

The White Peak is dominated by enriched grassland used for pastoral agriculture; however a number of meadows survive supporting species of wildflower such as oxeye daisy and yellow rattle (P.D.N.A. 2009b). Local fauna include avian species such as skylark, curlew and lapwing (Smith and Sykes 2009). Crested newts can be found in dewponds and the woodlands today support marsh tits and varieties of warblers alongside a number of invertebrates (P.D.N.A. 2009b; Smith and Sykes 2009). The Wye and Dove rivers are both known for trout and a species of native freshwater crayfish (Smith and Sykes 2009) while the natural caves and abandoned mines across the White Peak are home to several species of bat (P.D.N.A. 2009b). The steep slopes of the dales are species-rich areas supporting varieties of orchids, rockrose, wild thyme and a number of other species, which thrive on lime-rich soils (P.D.N.A. 2009b).

The varied ecosystems of the Peak District provide a diverse range of ecological environments, which in turn offer a variety of ecosystems and diverse sets of resources to the inhabitants of the region. The variation in land formations and environmental zones make it possible to orient oneself quickly within the landscape and appreciably illustrates the interdependent relationships that exist between the flora and fauna, geography and geology. Such insights into the geographies of the Peak District are not simply passing observations but serve to remind us how inhabitants in the past might have understood and navigated their surrounding in the absence of geological maps and ecological guides. Traversing the various ecological zones may have been a central issue or, in combination with the distinct features, an informative guide to movement through the landscape and in the acquisition and collection of different resources.

4.3. The Late Neolithic and Bronze Age in the Peak District

There are a number of issues in discussing the landscapes and habitation of the Peak District during the Late Neolithic and Early Bronze Age . Not least among these is the radiocarbon dating of sites and monuments within this region. Although antiquarians and archaeologists have spent years compiling and publishing evidence for all periods within the Peak District, much of the excavation and recording of sites was conducted in the 19th century under the care of antiquarians such as Greenwell, Bateman, and Carrington (Bateman 1848; 1861; Greenwell 1877). Therefore the dating resolution in the Peak District is not as particularity detailed. The dates that are available for the Late Neolithic and Early Bronze Age come primarily from the mortuary contexts and specifically from 187 of the round barrows that are a prominent feature within this region (Barnatt and Collis 1996; Brightman and Waddington 2011). Based on structural similarities with the dated examples, another 443 undated barrows may date to the same period, ranging from the Late Neolithic to the Early Bronze Age , roughly 2500 – 1500 BC (Barnatt 1999b; 2000; Barnatt and Collis 1996; Brightman and Waddington 2011). The distribution the number of these sites shows a high population density, or at least a dense population of deceased individuals placed in barrow burials (Barnatt 1996b; 1999b).

These Late Neolithic / Early Bronze Age barrows do not stand alone in the monuments of the Peak District, but are found distributed in a landscape with a number of other Neolithic monuments, including: chambered tombs, long barrows and henges (Barnatt 1996b; Barnatt and Collis 1996). The distribution of the barrows is densest on the Limestone Plateau of the White Peak, and particularly in the southwest where visibility is more restricted by the severely undulating topography (Barnatt and Collis 1996; Brightman and Waddington 2011). Far fewer barrows are located within the gritstone uplands to west of Ecton or in the higher Dark Peak to the far north. The barrows that have been excavated show a pattern of both inhumation and cremation burials, typical for this period (Barnatt 1999b).

Multiple burials within a single barrow are also common within the excavated examples.

In contrast to the plentiful evidence for mortuary practices, the evidence for activity and life during the Late Neolithic and Early Bronze Age is far scarcer (Barnatt 1987; 1996b; 1999b). At known and possible habitation sites, such as: Swine Sty (Machin 1971; Machin 1975; Richardson and Preston 1969); Aleck Low (Garton 1991; Hart 1985); Big Moor, and Gardom's Edge (Ainsworth 2001), the distribution of sites relative to round barrows shows a pattern consistent with each community constructing and maintaining their own monuments (Barnatt 2000; Machin 1971; 1975; Richardson and Preston 1969). Rather than barrow burials being the preserve of the elites, Barnatt (2000) has suggested this distribution shows the use of barrows by the community themselves. Although sites relating to the activities of life are rare during this period in the Peak District the sheer number of barrows alludes to a fairly high population (Barnatt 1996b; 1999b; 2008).

The Late Neolithic and Early Bronze Age inhabitants of this region likely took part in a complex pattern of seasonal use and movement across the landscape, reflecting traditional rights of tenure over broad areas of the Peak District and the lands immediately surrounding the region (Barnatt 1999b; 2000; 2008; Kitchen 2001). There were specific locals that would have been suitable for longer term habitation, such as Swine Sty (Machin 1971; Machin 1975) and Big Moor (Ainsworth 2001), while others would have been part of a seasonal pattern of use; however, through the Bronze Age there is increasing evidence for the prolonged use of specific sites (Ainsworth 2001; Barnatt 2008)

Relatively little direct palaeo-environmental information is available in the Peak District. However, what is available points towards a decline in woodland in the region. Environmental profiling presents a shift towards non-arboreal pollen in samples collected from East Moor, near to the site of Gardoms Edge, alongside the presence of cereal pollen around 2200 BC (Hicks 1971). By the Bronze Age there may have been extensive clearances in the Peak District's central limestone plateau. A species of beetle associated with grassland has been identified in an Insect assemblage from Langford; however, this same assemblage also shows the presence of mature woodlands. Stands of mature oak, beech, lime, elm, ash, hazel and alder still persisted, especially in areas not as attractive for cultivation or pastoral clearance (Bishop 1999; Clay 2001). The stark uplands of the Peak District, now covered by peat growth, are also the product of human interference. The high moorlands of both the Dark Peak and the Southwest area were largely cleared during the Bronze Age, possibly in the search for additional pasture or farmland (Barnatt 2008; Brightman and Waddington 2011).

The unique topography, hydrology and geology and resultant disparate ecosystems of the Peak District have the potential to provide an exceptional range of resources for the initiated to draw upon. Employing a *chaîne opératoire* approach provides a useful outline with which to consider the available and necessary resources upon which communities would have drawn in the fulfilment of activities related to copper production. It begins with the collection and preparation of materials to be employed in the extraction of copper ore.

Among mining sites in Britain it is the hammer stones that provide the initial evidence for Bronze Age mining Activity. In some cases locally available rock was employed although in many others special cobbles were brought to the mines from some distance. Gritstone and limestone were readily available in the immediate vicinity of Ecton; however, many of the hammer stones recovered from this site were quartzite. The availability of this material in the Dove and Manifold Valley has been assumed, but not established. The local geology does not suggest these materials were local and may have had to be transported to the mines (Pickin 1999). The nearest likely source of quartzite cobbles would be from much later Triassic deposits such as outcropping bunter deposits on the margins of the carboniferous landscape (Guilbert 1994a). A full review of these outcrops is not currently available, but Bunter Beds have been reported at both Hulme and Acton quarries on the west and south edges of the Peak District respectively, roughly 15 to 20 km from Ecton (Steel and Thompson 1983). Fieldwork will test the availability of quartzite in the Manifold and Dove drainage systems.

Antler is a resource available within the diverse ecosystems of the Peak District. Its discovery in Bronze Age contexts implies the exploitation of wild game, although shed antler could be collected without hunting the animals and can be seen as a highly portable resource. The native species of deer in Britain are Red deer and roe deer; both of these species live in woodlands and forests within the Peak District (Forestry Commission 2012) and a range archaeological evidence establishes their presence in this region during the Neolithic and Bronze Age. Bone tools could be sourced from either wild or domesticated animals and are again a portable material. They also represent the potential exploitation of different environments with deer from woodland habitats and the reliance on, or clearance of pasturage for domesticated animals. Other organics that have not been preserved include rawhide and other animal products, for use in the hafting of hammer stones or the making of carrier bags for the removal of ore and gangue from the mine. Other materials may have been used in connection with, or in place of animal products, such as withies for hafting or reeds for carrier baskets. Evidence from Copa Hill (Timberlake 2003b) and Mount Gabriel (O'Brien 1994) have demonstrated the range of organics used in the operation of the mines that have only been preserved owing to the conditions at those sites.

Timber for fire-setting, if it was practised at this site, would also have come from woodlands, and represents further interdependence on, and understanding of, the local area and the available resources. While it is not possible to trace any modern woodland as far back as prehistory, modern woodlands do grow on the sheltered slopes and river valleys including the Manifold valley (Barnatt and Smith 1997a; Dalton et al. 1988; P.D.N.A. 2009b). A further issue would have been illumination in the subterranean chambers believed to have existed at Ecton. All of these needs would have had to be addressed prior to the commencement of mining and draw on a range of resources from the variety of ecosystems existent in the landscape surrounding Ecton.

The extraction of copper ore was different from the collection of the other resources in that the copper deposits are a fixed and immobile point. Numerous copper mines are distributed though north Staffordshire and in particular along the Manifold river system. While these are better known from the post-medieval period, they represent a resource that may have been available in later prehistory (Porter and Robey 2000). It should be noted that no evidence of Bronze Age mineral exploitation has yet been located other than at Ecton. After the ore is won it must be processed, a process that may or may not have included washing. For this the stone hammers are again important to further crush the mineral. Sources of water, if required, were not in short supply, issuing from several springs as well as the Manifold River immediately below the Ecton mines.

In order to efficiently smelt the prepared ore, a number of other materials become important. Fuel to generate the intense heat, either wood or charcoal, depends again on the woodland. A need to control the atmosphere to generate oxidising or reducing conditions as required necessitates some kind of structure. Based on the scant evidence recovered from other sites on the British Isles this could be a simple hollow in the ground lined with stone or clay (Chapman 1997; Jones 1999; O'Brien 2004); however Alpine and Mediterranean models have shown the potential in more complex stone and clay furnace structures (Doonan 1999; Ottaway 2001). A third alternative is an open mouthed crucible placed within a bowl hearth as seen in the Southern Urals and the Iberian Peninsula (Koryakova and Epimakhov 2007; Pitman *et al.* forthcoming; Rovira 2002; Rovira and Ambert 2002), and the possible later Bronze Age in metal making site in Ireland (Liversage 1968). Clay is another resource that is readily available within the Peak District and is particularly plentiful in Staffordshire and there is an ongoing project to source potential clay deposits exploited in the Peak District during the Bronze Age. Despite the complex and diverse geology of this region the patterns of sedimentation are strikingly similar; it is the choices and uses of temper that appears to be more easily traced (Cootes Forthcoming). Temper was also important in metallurgical vessels to strengthen the clay whether it was used in a furnace or crucibles (Andrews and Doonan 2003; Sinopoli 1991). The kind of temper that may have been used to strengthen metallurgical ceramics in Britain can be inferred from casting crucibles and moulds, which used both sand and organic tempers (Needham 1980; Needham 1991; Ó'Faoláin and Northover 1998), although these may not be representative of materials used in smelting.

Tempered clay was also likely used in tuyères, the piece of the bellows or blowpipe that directed airflow into the hearth or furnace in order to raise the temperature and exert more control on the internal atmosphere. The bellows themselves were tools that combined a number of different resources including clays, temper, wild or domestic animals for hide and/or leather and woodland for withy or structural timber (Tylecote 1986). Finally, a flux [sand, iron oxide or lime] may have been needed to aid the formation of slag in order to facilitate the separation of copper metal from the gangue.

4.4. Metal Production and Consumption in the Peak District

The earliest copper and bronze objects in Britain are generally thought to be halberds and flat axes, both the thick and thin butted Lough Ravel, Ballybeg and Growtown styles (Northover 1980b). These objects are typically associated with the arsenic laden metal type A, the likely source of which is Ross Island, in Southwest Ireland. Few examples of these have been recovered in the Peak District, although a flat copper axe was found at Sycamore cave during excavations in 1988-1989 (Houdmont 1989; 1991). This artefact has not been subjected to trace element analysis and the typology of the metal from which it is made remains unknown. This axe was found in association with ceramics, flint scrapers, animal bones, and the remains of at least 2 infants (Houdmont 1989; 1991). The site has been tentatively dated to the end of the Neolithic period, making it among the earliest metal object in the Peak District.

As with the copper axe from Sycamore Cave, the majority of recorded finds come from funerary contexts, although these are predominantly from the round barrows that accent the landscapes of the Peak District. This means that the known distribution of metal artefacts from the first millennium of metal production and use is again dependant on the work of antiquarians who were so enamoured by these mortuary monuments. The results of their labours are variably recorded in volumes produced by themselves or their contemporaries (c.f. Bateman 1848; 1861; Greenwell 1877; Rooke 1796). There have been relatively few modern excavations of barrows within the Peak District. Barnatt (1996) identifies 25 sites, some of which were ostensibly from an earlier Neolithic context. This again presents a relatively poor dating resolution for both sites and the recovered material therein.

Among the more common metal objects from the largely Late Neolithic – Early Bronze Age barrows are bronze daggers. Examples have been recovered from Cardeer Low, Parsely Hay, and Net Low (Barnatt 1996a: 44), all round barrows found on the central limestone plateau of the Peak District. Additional exotic items such as jet, amber and dolphin bones have also been recovered from funerary contexts on the limestone plateau. Metal objects were not recovered from all of the excavated barrows. In fact relatively few copper or bronze objects have been found from known or suspected Late Neolithic - Early Bronze Age contexts. Only five bronze objects have been recovered from among the 65-recorded barrows located in a five km radius of the copper mines at Ecton. These include: a bronze amulet found in a bowl barrow near Bincliff Mines (PRN: 00404 – MST4); a bronze bracelet recovered from Three Lows Barrow (PRN: 00390 – MST3); a bronze dagger found inside Lid Low Barrow (PRN: 00359 – MST3); a bronze Awl from Hillside Barrow (PRN: 00356 – MST3); and a bronze sword found in Brund Low (PRN: 00138 – MST1) although the dating and origin are uncertain and this artefact is now lost (Barnatt 1996a; Staffordshire HER 2010).

Cave sites are another location for the recovery of copper and bronze objects. Besides the previously mentioned Sycamore cave, bronze objects have been reported from both Thor's Cave and Thor's Fissure Cavern, within the Manifold Valley, South of Ecton Hill. However it is doubtful that these artefacts date from the Bronze Age. Metal objects were recovered from Thor's Cave in 1864-5 during excavations that also found recovered Beaker and Bronze Age pottery and a crouched inhumation (Carrington 1866). However, the majority of the metal artefacts appear to have been from subsequent depositions from later periods, including: an armilla, two ring pins, two fibulae, and a brass Roman coin featuring the Emperor Hadrian. Excavations in Thor's fissure cavern from 1927 to 1935 also recovered a number of artefacts and human remains, including bronze artefacts. Neither assemblage has been solidly dated. The ceramics recovered from Thor's Fissure Cavern have been classified to the Late Neolithic, Iron Age and Romano-British periods respectively.

The majority of, though not all, stray finds of metalwork come from within the Dark Peak. These are usually isolated finds, although they occasionally occur in association with other material. Noted stray metalwork finds include side-looped spear heads, palstaves and long-bladed rapiers (Northover 1980b; Staffordshire HER 2010), although these types of artefacts are more commonly associated with Middle Bronze Age industries (Northover 1980b).

4.5. A Brief History of Mining At Ecton during the Historic Period

There is a long history of mining at Ecton extending back to English civil war, and possibly even earlier, with records of the sale of ore and an expenditure of £200 on the Devonshire liberty prior to the civil war (Porter and Robey 2000). The historic records are by no means complete, but a reasonably comprehensive history of the mines has been reproduced in several sources (c.f. Barnatt 2002; Forthcoming; Barnatt *et al.* 1997; Porter 2004; Porter and Kirkham 1998; Porter and Robey 2000; Robey 1975; Robey and Porter 1972). The historic mining at Ecton has typically been divided into three periods: activity prior to 1760, the peak of mining 1760 – 1820, and activity since 1820.

4.5.1. Historic mining Prior to 1760

The title, or ownership, of the mineral bearing zone at Ecton is divided between the Burgoyne family and the Earl of Devonshire, later the Duke of Devonshire. Although the Burgoyne family sold their land at Ecton in 1648, prior to any known mineral exploitation in the area, they retained the mineral rights as well as concessions for the operation of any mines on the land, including rights of access and lodging for workmen (Porter and Robey 2000; Robey and Porter 1972). Although there is no record of a mine in operation at the time of, or prior to, the sale the implication of this caveat is a familiarity with the mineral wealth lurking below the surface.

The first record to specifically mention mining at Ecton is from 1660 when the then Earl of Devonshire "reopened his Ecton mines" (Barnatt et al. 1997: 38). For the next five years the Earl of Devonshire operated the Ecton Mines on his own liberty. Although it is not clear which of the workings existed or were in operation at this time it is likely that either Ecton Pipe or Stone Quarry Mine, or perhaps both were being operated. By 1664 the output of the mines had fallen and in 1665 Devonshire leased the mines to Jacob Mumma (Barnatt *et al.* 1997; Morton and Robey 1985). The extent of activity during this lease is uncertain, but Stone Quarry Mine was expanded (Porter and Robey 2000). Unique bore holes in Stone Quarry mine reveal the first use of gunpowder at Ecton during this time, making it among the earliest uses of gunpowder in mining in Britain (Barnatt *et al.* 1997; Ford 2000; Porter and Robey 2000; Robey and Porter 1972). Similar drill holes have been identified in the upper levels of the entrance E9, which led to the main Ecton Pipe. Barnatt *et al.* (1997) have dated both examples to the 17th century based on bore and depth indicating that the upper portion of the Ecton Pipe was being worked prior to 1700.

The original mine(s) on the Devonshire liberty were reportedly re-opened and drained in 1707 for a tentative and short-lived venture (Hooson 1747; Robey and Porter 1972). On November 1st 1723, a 21 year lease was agreed between the 3rd Duke of Devonshire and a group of eight adventure miners (Porter and Robey 2000; Robey and Porter 1972). They began to construct the Deep Ecton Level (Barnatt 2002; Porter and Robey 2000). By 1739 the adventurers had abandoned the sough and surrendered the lease (Robey and Porter 1972). At this point the focus for mining activity changed and moved from the open shaft entrances, and possible Bronze Age activity, on the north western arm of Ecton hill to a point further down slope. On December 12th 1739 a new 21 year lease was agreed between the Duke of Devonshire and a new company of five individuals. It was during this lease that the Deep Ecton Level was completed to intersect with the Ecton Pipe, indicating that by this time the mines had reached a substantial depth (Barnatt 2002; Porter and Robey 2000). Engine shaft, elsewhere called Roose's Shaft, Dutchman level, Apes Tor shaft, and the 34 fathom, or Apes Tor, level were all begun during this lease (Barnatt 2002; Barnatt *et al.* 1997; Porter and Robey 2000). The focus of development was now on the lower reaches of Ecton Hill and the Manifold Valley. Dressing floors were already established in the Manifold Valley, at the foot of Ecton Hill by 1760 and smelting also reportedly took place at Ecton from as early as 1764 (Porter and Robey 2000).

During the same period on the Burgoyne Liberty three mines were in operation. Records from 1672 reveal that two mines were worked, with gunpowder, by Sir Richard Fleetwood, while the third was operated by another party that included three members of the Clayton family (Barnatt and Smith 1997a; Porter and Robey 2000). The mines were all on Hanging Bank, a name that applied to the northwest crest of Ecton, and were all producing lead (Barnatt et al. 1997; Robey 1975). Clayton Grove (Clayton Mine), Water Work (Waterbank Mine), Clay work (Clay Mine) and Bowler Grove (Bowler Mine) were all actively worked between 1737 and 1744 (Porter and Robey 2000), but the details, extent and duration of the leases at this time are unknown. Payment for damages to Chadwick farm were made in 1743 and again in 1759 indicating that mines were in operation at these dates (Porter and Robey 2000; Robey and Porter 1972). In 1753 Thomas Gilbert agreed a thirty-year lease with Sir Roger Burgoyne that specifically excluded Clayton Mine, implying it was still under another lease. In 1755 Gilbert agreed a separate 21-year lease with the Duke of Devonshire to drive and operate a sough, now Clayton level, through the Duke's land to intersect with Clayton Mine (Porter and Robey 2000).

4.5.2. The Peak of Historic Mining 1760-1820

From 1760, with returns from the mine increasing, the 4th Duke of Devonshire appointed an agent to supervise the running of the mines on his behalf (Porter 2004; Porter and Robey 2000; Robey and Porter 1972). Sometime between 1763 and 1765 the 34 fathom level, or Apes Tor level, and shaft were completed at the north end of the hill (Barnatt 2002). A recently identified terraced track enabled the movement of ore from the gin circle at Apes Tor to the processing floors (Barnatt 2002). A new shaft was also sunk near the Ecton Pipe in the 1760s (Barnatt 2002). In 1767-68 the Apes Tor Level was widened and made into a boat level, making it one of the earliest examples of a subterranean boat level in Britain (Barnatt 2002; Porter and Robey 2000). It was subsequently widened in 1780 (Porter 2004; Porter and Robey 2000). Barnatt (2002) also suggests that the Deep Ecton Level was converted to a second boat level between February and June 1769 and in 1774 the entrance to the Deep Ecton level was re-driven because of a collapse in the original entrance (Barnatt 2002).

In 1783 a water engine, or 'flop-jack' engine, was installed in a purpose built subterranean chamber adjacent to the Ecton Pipe mine. This simple engine was fuelled by water brought in from the river at Apes Tor in a new sough, now known as the Apes Tor Sough, driven above the Apes Tor level at river level, between 1780 and 1783 (Barnatt 2002). The flop-jack engine pumped water up a purpose made shaft, known as the Great Shaft, from deep in the mine, keeping the lower levels dry for over 40 years (Barnatt 2002; Robey and Porter 1972). In 1788 a Boulton and Watt steam powered winding engine was finally installed on top of Ecton Hill, at the 1767 New Engine Shaft (Barnatt 2002; Porter 2004; Porter and Robey 2000; Robey and Porter 1972). The engine house is still visible on Ecton hill.

A note pencilled in the account books in 1790 states simply "Mine Failed" (Porter 2004; Porter and Robey 2000). The miners had exhausted the accessible deposits of the copper rich Ecton Pipe. However, The Duke of Devonshire continued work at Ecton. New trials were explored including the East Ecton Level on the back of the hill from 1793 to 1796 (Barnatt 2002). Chadwick sough was begun in 1760 on the back of Ecton on the Burgoyne Liberty and an engine shaft was sunk at Chadwick mine the same year (Porter and Robey 2000; Robey and Porter 1972).

In 1804 the Duke of Devonshire was able to take out a new, thirty-year lease on Clayton Mine (Porter and Robey 2000). Chadwick Sough was also re-opened in

1804/5, which involved the removal of the deads that had been stacked in the mine (Robey and Porter 1972). Two steam engines were purchased during the Duke's lease of the Clayton Mine, one in 1812 pumped water out of the mine and the other in 1814 was employed to raise material (Porter and Robey 2000; Robey and Porter 1972). The latter was installed underground in the Clayton Adit, a unique feature of the mines at Ecton in the 19th century. The developments of mines on the Burgoyne liberty had little impact on the suspected Bronze Age remains and were worked predominantly for lead rather than copper

Later reworking of earlier trials may have impacted the Early Bronze Age features. Between 1811 and 1818 trials were dug at Gould Ecton, Hamnook, Bowler Mine, Dutchman Mine and Chadwick Pasture (Porter and Robey 2000). By 1818 Bag level extended from Clayton Mine almost to Bag Mine, though the two were never joined, and Goodhope level had intersected a shaft at the Lumb (Porter and Robey 2000). This is the only recorded instance of post medieval activity connected to the Lumb and may have impacted subterranean workings, if they existed here, but did not greatly interfere with the surface features. In 1819 Birches level was driven into the hillside hoping to intersect veins at Hamnook and Gould Ecton

4.5.3. Mining and activity since 1820

Between 1818 and 1825 there was large scale reworking of old tips and waste ores owing to developments in mineral extraction from the Cornish mines (Robey and Porter 1972). It is possible that Bronze Age tips may also have been disturbed as old tips were reworked. A Cornish style stamps yard was built downstream at Swainsley and a tramway was installed to take material from the old tips at Ecton to the new stamp yard (Porter and Kirkham 1998b; Porter and Robey 2000; Robey and Porter 1972). At the same time a weir was built opposite the Clayton adit to divert water down a leat to the new yard where the stamps were driven by a waterwheel (Porter and Kirkham 1998b; Porter and Robey 2000; Robey and Porter 1972).

In 1823 an overshot waterwheel replaced the water engine, or flop-jack engine, in the Ecton Pipe mine (Porter and Robey 2000). The Duke of Devonshire ceased works in the Ecton Mine at the end of 1825 (Porter and Robey 2000; Robey and Porter 1972); however, the smelting works continued smelting and calcining waste ores until 1826 (Porter and Robey 2000).

The mines were not long abandoned and there are at least 11 separate enterprises on record that attempted to further exploit mineral resources at Ecton, with little success, between 1826 and 1890. Many of these were content to clean out known veins or scavenge the old tips (Porter and Robey 2000). It is unclear if any of this activity was conducted in Stone Quarry Mine, or relation to the Lumb, but may be unlikely if these workings had been previously cleared of copper ore. After 1854 the mines below adit level were allowed to flood (Porter and Robey 2000). Ecton remains flooded to the adit level.

The mines on the Burgoyne liberty lay abandoned from 1822 until 1836 when A 21-year lease was established and Waterbank was drained, but by 1839 it was once again abandoned in favour of Clay, Goodhope, and Bag Mines (Porter and Robey 2000). Work progressed in Goodhope level, where galena was found near the northern end, towards the Lumb, but in 1845 work stopped in all but Clay and Clayton mines (Porter and Robey 2000).

Mining companies continued to work leases on both the Devonshire and Burgoyne Liberties, even jointly after 1851 (Porter and Robey 2000). There are reports of the expansion of several of the mines, adits and soughs at Ecton by one or another of the companies that worked the mines, but only one confirmed new trial was begun (Barnatt 2002; Barnatt *et al.* 1997; Porter and Robey 2000). Fly Mine, on the Devonshire Liberty, was commenced in 1854 (Barnatt et al. 1997). All mining finally stopped at Ecton when The Ecton Co. Ltd, which had held leases on both liberties from 1883, ceased operating (Porter and Robey 2000). The leases formally ended at the beginning of 1891, but no mining is known to have occurred after 1889 (Porter and Robey 2000).

4.6. Landscape and Prehistoric Archaeology at Ecton

4.6.1. The Landscape

Ecton Hill is a limestone ridge approximately 2.5 km long and up to 1.3 km wide, rising to a total height of 369 m OD, 270 m above the Manifold Valley (Barnatt et al. 1997; Ordnance Survey 2002). This is by no means the highest point in the Peak district, but it is a distinctive feature and among the highest points within its surroundings. Ecton Hill forms part of the western bank of the River Manifold, which has helped to shape the hill's steep western slope. The focus of mining activity was the steep northwest face of the hill (Barnatt *et al.* 1997; Porter and Robey 2000), which rises approximately 199 m over a distance of 275 m and has an average slope angle of 63 degrees. The valleys encircling Ecton hill accentuate its height and adds to its impact within the landscape.

Ecton Hill is located between Warslow and Wetton in North Staffordshire part of the western Peak District. It is a distinct feature among a western ridge of hills that extend the limestone plateau westward in the southern extremity of the White Peak. Ecton is the most northern point in this range just to the southwest of Hartington and casts a long shadow over lower ground to the north. The River Manifold flows south immediately to the west of Ecton while the River Dove flows almost parallel only a short distance to the east. There are far fewer springs on the limestone plateau than can be observed in the Moorlands of the Dark Peak, but a number are found in the immediate vicinity of Ecton Hill. One flows roughly north along the back of Ecton Hill to empty into the River Manifold just north of Apes Tor, whilst another seasonal stream runs south towards Wetton hill. A further two unnamed springs flow east almost parallel to the north of Narrowdale and Gratton hills between Ecton and the River Dove and one other joins the Manifold near Hulme End (Ordnance Survey 2002).

4.6.2. Geology

Ecton Hill is one of a series of limestone reef formations on the edge of the White Peak plateau that, like the rest of the White Peak was formed in the Dinantian period of the lower Carboniferous, 354 – 310 million years ago (Ford 2000). The hill itself is comprised of Ecton series limestone, overlying the Milldale limestone series, which forms the geology of the adjacent Manifold Valley. This is a generally fine-grained limestone with numerous 'mud-mounds' or knoll-reefs (Ford 2000). These 'mud-mounds' outcrop along much of the Manifold Valley south of Ecton, forming the core of the Ecton anticline, and extend below the hill at depth (Ford 2000). The total depth of this deposit is unknown, but it is at least 700m. Overlying the Milldale limestone is the Ecton Limestone that forms the hill (Critchley 1979). This is a thinner bedded, shallow water limestone formation and is composed of alternating layers of dark, fine-grained limestone and thin shale, with the limestone dominant (Critchley 1979; Ford 2000). This formation outcrops and is visible at Apes Tor, at the north end of Ecton Hill. There are also sporadic bands and nodules of chert within this formation (Ford 2000). The Ecton Limestone forming Ecton hill is at least 225m thick and occasionally includes massive limestone beds within the usually thinly bedded formation (Ford 2000).

Ecton Hill forms an asymmetric north-south anticline (Aitkenhead *et al.* 1985; Ford 2000). The tight folding in this region is visible in small scale north – south folds in the exposed rock at Apes Tor as well as within the mine adits (Critchley 1979; Ford 2000). Within the mines these small-scale folds were well known to miners who referred to the anticlines as saddles and the synclines as trough saddles (Ford 2000; Porter and Robey 2000; Robey and Porter 1972; Watson 1860). The mineral veins, however post-date the host rock formation and folding episodes as main ore bodies are steeply inclined, sometimes close to vertical.

4.6.3. Mineralogy

Mineral deposits are common within the limestone plateau of the White Peak. The Derbyshire lead fields have been mined since the Roman period (Barnatt 1999a; Barnatt and Penny 2004) as evident in the early workings of the mines (Hodges 1991) and in the recovery of lead pigs stamped with Roman identifiers (Branigan *et al.* 1986). Large mineral deposits of lead, copper and zinc, among others, were found within the limestone of the White Peak, but the events that led to their mineralization are not clearly understood in the region. It is not clear if all of the mineralization is due to a single genetic system or if there were separate events that led to the deposition of minerals in north Staffordshire and Derbyshire.

Ecton Hill is on the edge of the Derbyshire lead fields and it is usually accepted that the northeast Staffordshire mineral deposits are an extension of the Peak District lead field. This is reinforced by the presence of lead in the mines at Ecton (Ford 2000). In fact, several of the historical mines were worked for the lead ore galena [PbS], rather than copper during the post-medieval period (Porter and Robey 2000). However, Ixer and Townley (1979) have suggested that Ecton should not be included as a part of the same ore field because of the distinct mineral sets present in the Derbyshire and Staffordshire deposits, and should therefore be considered distinct. This has been followed with more recent research that has proposed that, while the mineral field appear to be broadly contemporary, the proportions of copper and fluorspar present at Ecton and in other mines of northeast Staffordshire suggest a different source (Ford 2000; Masheder and Rankin 1988; Quirk 1993).

The mineral beds of northeast Staffordshire fall into three categories: Lodes, Saddles and Pipes all of which are present at Ecton (Ford 2000). Lodes are steeply dipping to nearly vertical fissure veins, such as Vivian's Lode in Clayton Mine and are significantly smaller than the lead rakes known in Derbyshire (Ford 2000). Saddles are where mineral deposits have formed along the bedding planes on either side of the folds (Ford 2000; Watson 1860). Mineral deposition along these bedding planes may be an infilling of a void created during folding, or replacement of less resistant shale within the limestone (Ford 2000). Finally, pipes, in Staffordshire mining terms, are more or less cylindrical ore bodies that are steeply inclined or vertical and descend to great depths. Pipes do not follow the local bedding, but cut through the strata (Critchley 1979). The pipes on Ecton are found within the highly folded limestone on the eastern flank of the Ecton anticline (Ford 2000). The position of the pipes at Ecton may be related to the formation of faults beneath the anticline suggested by Corfield et al. (1996; Ford 2000).

The predominant copper ore in the Ecton Mines was chalcopyrite [$CuFeS_2$], a primary sulphide ore (Critchley 1979; Ford 2000; Ixer and Townley 1979). Several other enriched copper sulphide minerals were also present including chalcocite [Cu_2S], erubescite or bornite [Cu_5FeS_4] and covellite [CuS] (Ford 2000). These minerals all share an iridescent brassy colour. Secondary mineralization also occurred at Ecton where water percolated through the sulphide ores creating copper carbonates such as azurite [$Cu_3(CO_3)_2(OH)_2$] and malachite [$Cu_2CO_3(OH)_2$] (Ford 2000). These are very distinct and highly visible minerals owing to the blue and green colouring. Ford (2000: 11) also noted the presence of the secondary oxide minerals cuprite [Cu_2O] and tenorite [CuO]. The presence of native copper in some of the deep mines was also reported in the historic mine records (Porter and Robey 2000; Robey and Porter 1972) and has been observed by Ford (2000). The primary vein material, which accompanied copper mineralization, is calcite [$CaCO_3$] with occasional dolomite (Critchley 1979; Ford 2000).

Other rare minerals identified at Ecton include the sulphides bravoite [(Fe, Ni) S2], millerite [NiS], and arsenopyrite [FeAsS] (Ixer and Townley 1979; Mostaghel 1984; Starkey 1983). Zinc blende, or sphalerite [ZnS], and Galena [PbS] were also present at Ecton (Ford 2000; Porter and Robey 2000; Robey and Porter 1972). Trace element analysis has revealed higher concentrations of nickel [Ni] cobalt [Co] antimony [Sb] bismuth [Bi] and silver [Ag] in the ores at Ecton than elsewhere in the South Pennines (Ford 2000; Mostaghel 1984). While there is no record of silver sales from the Ecton Mines, 13.3 kg [475 ounces] of silver was extracted from the galena extracted at the Dale mine, across the Manifold valley from Ecton, in 1861 (Mostaghel 1984 as in Ford 2000). Several other combined oxidation products have also been identified at Ecton including smithsonite [$ZnCO_3$], aurichalcite [$(Zn,Cu)_5(CO_3)_2(OH)_6$], rosasite [$(Cu,Zn)_2CO_3(OH)_2$], serpierite [$Ca(Cu,Zn)_4(SO4)_2(OH)_6 3H_2O$] and linarite [$PbCuSO_4(OH)_2$]; however the majority of samples were collected from waste heaps and provenance within the mines can not be established (Braithwaite 1991; Braithwaite *et al.* 1963; Braithwaite and Knight 1968)

4.6.4. The Prehistoric Archaeology of Ecton

Within the landscape around Ecton are a number of round barrows, cave sites and find sites that are all dated to, or suspected to date to, the Late Neolithic or Early Bronze Age . A total of 98 sites, not including the mines themselves exist within a relatively small area, within five km of the copper mines. Of these, the vast majority are connected with funerary contexts, some 65 are barrows while a number of cave sites have also turned up evidence of burials that may date to this period.

Unlike most of the other previously recorded copper mining sites in Britain, antiquarian interest in Ecton Hill was not initially due to the discovery of 'owld man workings', but because of the presence of a number of barrows along its ridge. Thomas Bateman was an antiquarian who lived locally and actively investigated Bronze Age barrows throughout South Yorkshire, Derbyshire and Staffordshire in the mid-19th century (Bateman 1848; 1861). His contemporary, Mr. Samuel Carrington was also involved in the investigation of barrows in the Peak District and, while publishing few of his own accounts, his excavations can be found included in the 1861 volume by Bateman.

Ecton Hill Barrow opened by Mr. Samuel Carrington in 1848:

> On the 18th of May opened a barrow on a hill near the celebrated Ecton Mine called hanging bank – found deposit of calcined human bones – the rest having been removed as recorded by Plot in his history of Staffordshire in 1686 "In

> digging open a lowe on Ecton Hill near Warslow there were found mens bones of an extraordinary size". The calcined bones were also disturbed at this time. They were found in association with a large bone pin 2 spear points and 2 arrowheads of flint all of which had passed through the fire. A piece of stags horn was found in another part of the mound (Bateman 1861: 111-112)

When Bateman revisited the same mound he recorded a further two un-burnt tines of red deer antler, boars tusk and several deposits of 'burnt or calcined' bone. He also recorded "more human bones, which had been disturbed by miners, who finding lead in the tumulus, had concluded it to be the site of an ancient bloomery or smelting place" (Bateman 1861: 147). This is a claim that has yet to be re-investigated, but presents an intriguing possibility.

On May 9th 1850 Carrington opened a second Barrow on the crest of Ecton "a few hundred yards south of that examined on the hang bank" (Bateman 1861: 164). Within this barrow Bateman (1861) reports 8 internments, a deposit of calcined bone and a few flint implements. In 1851 a third barrow on Ecton was opened, it too is recorded as being on the Hang Bank, 300 yards east of the first barrow (Bateman 1861). The only finds recorded are a small deposit of burnt bone and two pieces of flint (Bateman 1861).

The cave site mentioned earlier in this chapter, Sycamore Cave, is also in proximity to the Ecton Mines, although it avoided discovery until the 1980's. The Sycamore Cave deposit contained the remains of at least two infants, flint scrapers, ceramic vessels and a copper flat axe. As of writing the copper in the axe has not been subjected to trace element or lead isotope analysis and its possible relationship to the copper mines is unknown.

Speculation over the potential for prehistoric copper mining at Ecton first arose with the discovery of hammer-stones at the mines in 1855. The manner in which they were recovered is uncertain; one report indicates that Bateman himself entered the mines at Ecton and recovered them from an unknown location (Porter and Robey 2000), whilst another source proposes that Samuel Carrington secured them on Bateman's behalf (Pickin 1999). The hammer-stones received no mention in Bateman's volume, *Ten Year's Diggings* (Bateman 1861), nor are they included in the 1899 catalogue of the Bateman Collection at Sheffield City Museum (Howarth 1899). The only mention of their provenance is a hand written note accompanying them in the Weston Bank Museum stating: "found in ancient copper mine at Ecton in June 1855" (Guilbert 1994b; Pickin 1999). The note also reports the discovery of "sharpened pieces of stag's horns" (Guilbert 1994b; Pickin 1999) though whether the pieces of sharpened antler were recovered is unclear and their current location is unknown (Pickin 1999). The identification of 'stags horn' or antler tines in the barrows atop the Bronze Age mine where tools of a similar material were used may suggest a deeper connection between the barrows, or those there interred, and the mine.

The exploration of Ecton by Nellie Kirkham in the 1940's provided further detail about the extent of subterranean mining above adit level and the suspected prehistoric activity on the hill (Kirkham 1947; Kirkham and Ford 1967). In 1945 Kirkham discovered a chamber roughly 25-30m below surface, which she described as 'a worked out space, quite large' (Barnatt et al. 1997). Within the space she recorded four possible hammer stones along with several worn pieces of bone (Barnatt *et al.* 1997; Barnatt and Thomas 1998). These remains were not removed, but left *in situ*. Subsequent exploration of the subsurface features has found access to this chamber now blocked (Barnatt *et al.* 1997; Barnatt and Thomas 1998).

It was only after the discovery of hammer stones on the tips below the Dutchman level (Guilbert 1994a; 1994b) that a systematic search for evidence of prehistoric mining was initiated (Barnatt and Thomas 1998). The cobble tools recovered by Guilbert were found at the surface, below a level that connects to, or has connected to, several subsurface workings. This means that, unfortunately, it was not possible to use their discovery to pinpoint any specific workings as prehistoric.

4.6.5. Evidence of Mining

The most readily accessible evidence for prehistoric copper mining at Ecton is the growing assemblage of hammer stones that have been recovered from the site. As mentioned in the previous section the first examples of these were originally recovered in 1855, although they lack specific context and went largely un-noted for over a century after their recovery. An additional four hammer stones were recovered at the end of the 20^{th,} century below Dutchman's level and now reside in the collection of Sheffield City Museum (Guilbert 1994a; Guilbert 1994b). While these additional tools did no more to pinpoint the location of prehistoric workings, cursory analysis by Dr. R. Firman of the University of Nottingham revealed two of them to be either meta-quartzite or ganister, whist the other two are locally available varieties of millstone grit (Guilbert 1994a). If the first two are meta-quartzite then an origin in the Bunter beds, also known as Chester beds, is likely (Guilbert 1994a); outcrops of these deposits are not currently known in the vicinity of Ecton Hill. Ganister also represents a non-local rock type and either possibility would have required the stones to be brought to Ecton from an as yet undetermined distance (Guilbert 1994a).

In 1999 John Pickin was able to gain access to the original Ecton hammer-stones from the Bateman collection and provides a valuable description of the tools (Pickin 1999). Six of the ten tools form a group of "elongated quartzite cobbles with close pitted wear marks at both ends" (Pickin 1999: 17). One further tool is also a quartzite cobble with a similar lithology as the previous six, but is split and shows no damage at the ends (Pickin 1999). Pickin (1999) believes these to be identical in form and use wear to the two meta-quartzite cobbles recovered by Guilbert. Of the final three tools one is fashioned out of Millstone Grit, which is again similar to tools recovered by Guilbert; one is a granular sandstone, possibly a variety of Millstone Grit; and the final one is a banded muddy limestone cobble (Pickin 1999).

Following the recovery of the stone hammers at Ecton, exploration and survey of the mines was rejuvenated. Attempts were made to re-locate the chamber described by Nellie Kirkham, but unfortunately the access to the chamber was found to have collapsed (Barnatt and Thomas 1998). Subsequent exploration found no other access to the chamber, but it did lead to the recovery of an antler tool in an irregular working above Dutchman level and about 11.5m beneath the surface (Barnatt and Thomas 1998). The 207mm long antler tool was found on the floor of a steeply sloped working and it is not clear if it was in a primary context or had been dislodged from elsewhere (Barnatt and Thomas 1998). This fragment of antler was radiocarbon dated to the Early Bronze Age with a range of 1880 – 1630 cal. BC (3445+/-35 BP OxA-7466 calibrated to two sigma using OxCal). The tool end of the antler was naturally smooth with slight damage attributed to use-wear consistent with a picking or prising function based on experimental work (Barnatt and Thomas 1998; Timberlake 1990d). Analysis of the opposite end showed that it had been altered to accommodate a haft using a metal blade, which, given the dating of the tool, is presumed to be of bronze (Barnatt and Thomas 1998).

4.6.6. The Structure and Chronology of Bronze Age Workings at Ecton

Careful survey, including the most recent Ecton Mines project, has culminated in the identification of at least three areas of the on the hill where Bronze Age mining activity is likely to have occurred. These are: in the vicinity of the Ecton Pipe; Stone Quarry Mine, also called Dutchman's mine; and the Lumb, a diagonal opencast like feature directly down slope from one of the barrows surmounting the ridge of the hill (Barnatt Forthcoming; Barnatt and Thomas 1998).

Mining during the Bronze Age at Ecton exploited the presence of copper ore within the oxidation zone, above the water table, and the alteration of most of the chalcopyrite to secondary carbonate minerals, notably malachite and to a lesser degree cuprite, tenorite and native copper (Timberlake and Barnatt Forthcoming). Supergene minerals bornite, chalcocite and covellite were also present in this zone (Timberlake and Barnatt Forthcoming). The local geology would have made mining a relatively easy task, even at depth with well-vented and free-draining workings.

The identified episodes of prehistoric mining at Ecton Hill were in the second millennium BC. The earliest mineral exploitation appears to have been on outcrops of copper ore near the Ecton Pipe and Stone Quarry Mine (Barnatt Forthcoming). Although later exploitation has mostly obliterated the surface evidence, these were likely simple surface workings, which may have become opencast mines before delving underground, chasing the oxidised copper ores through mineral filled voids, clay filled cavities, and open karst features (Barnatt Forthcoming). The workings near the Dutchman's level are likely older than those of the Lumb. The mineralized Pipe formation at Ecton Pipe and Stone Quarry Mine were likely the more attractive deposits owing to the ease of access (Barnatt Forthcoming). Mining followed these deposits east west as well as down along the veins of oxidised copper minerals.

The primary evidence for Bronze Age activity is from the dating of five bone tools (Timberlake and Barnatt Forthcoming). These were recovered from a late 17th to early 18th century mining tip where they had been re-deposited. The spoil tip is located on the northwest side of the more northerly of two steeply inclined underground workings that make up the Stone Quarry Mine entrance. The dates suggest a range of between 2000 – 1750 BC to 1860-1570 BC (Timberlake and Barnatt Forthcoming). This more northern Stone Quarry Mine opening may be prehistoric in origin, although there is insufficient evidence at this time to substantiate that claim

The Lumb is a series of bench opencasts that followed a weak outcrop of mineralized dolomitic limestone uphill. The copper minerals seem to have been mined in a series of short inclined opencasts that followed the dip in the bedding of the country rock. These opencast were mined to a depth of 1-2 m and possibly deeper by working into the rock face and undercutting dolomitised limestone, creating a collapse. The sought after mineral could then be collected, with minimal deference to the sterile country rock, leaving large pieces of limestone *in situ* (Barnatt Forthcoming) As at the other locations, malachite was the primary mineral exploited at the Lumb (Timberlake and Barnatt Forthcoming). Many of the open features within the Lumb may only be karst features in the limestone country rock.

4.7. Summary

The Peak District is a region of diverse landscapes hosting a range of environments and a wealth of resources. The region has yielded a palimpsest of prehistoric archaeology from the Upper Palaeolithic onward. All the resources needed for primary copper metallurgy can be found within the Peak District, including one of only two known copper mining sites in England at which Early Bronze Age extraction has been identified. The Bronze Age copper mines are found amidst the post medieval mining remains, which have significantly altered the landscape and impacted the prehistoric archaeology of Ecton. In addition, smelt works and dressing floors operated in the Manifold Valley below the mines, further altering the landscape and possibly disguising or destroying prehistoric metallurgical remains.

Beyond the mines is a landscape that incorporates a number of environments and varied topography. On the White Peak, the undulating surface, deep river valleys and prominent hills create unique spaces that are visually restricted. The focus within this landscape is on the spaces reinforced by close horizons that constantly change as the viewer moves throughout the landscape. Individual places demarcated by barrows and/or special deposits may be seen as important based on their inter-visibility, or the lack thereof, with other sites or on their increased visibility within this landscape. This contrasts with the Dark Peak to the north and west of Ecton Hill where distant horizons and a uniform appearance over a wider area creates a more uniform sense of space and shifts the focus to place. This is further enforced by the availability of water on the Dark Peak and the shallow river valleys that help accentuate the appearance of a unified landscape and provide an impression of unrestricted visibility and access. Far fewer barrows are found on the Dark Peak and specific Bronze Age sites are more difficult to identify in the open spaces of this landscape. The formation of a methodology to interrogating these diverse landscapes will draw on the differing terrains and incorporate the history of mining and other activity at Ecton and within the Manifold Valley. The methodology, outlined in chapter five, will also engage with the known Bronze Age remains in the hinterland of Ecton.

5. Methodology: An Integrative Approach

5.1. Introduction

To date most archaeological field based investigations of primary Bronze Age copper production have been concerned with the selection and acquisition of copper ores and have therefore focussed on the survey and excavation of mining sites. Such studies have been to a large part directed by geologists keen to understand this aspect of ancient practice (c.f. Timberlake 1992; 1994; 2001). At the same time, the study of smelting has tended to be led by chemists and metallurgists working on artefacts in a laboratory setting in the hope that composition can be used to infer ancient practises (c.f. Craddock 1980; 1989; 1990; 1995; Moesta 1986; Northover 1980; 1989; Tylecote *et al.* 1977; Tylecote 1986).

Therefore, the programme of original fieldwork undertaken as part of this project incorporates field evidence relating to metal production and attempts to identify traces of the primary metallurgical taskscape in the landscape surrounding the Bronze Age mines at Ecton Hill. The potential for the recovery of evidence associated with primary copper production at Ecton was realized in the later part of the 20th century with the secure dating of mining activity to the Early Bronze Age (Barnatt and Thomas 1998). A number of copper alloy finds have been recovered from the vicinity of the copper mines including what appears to be an Early Bronze Age flat axe from Sycamore cave (Houdmont 1989; 1991). Whilst such finds cannot be considered evidence for the practice of primary metallurgy at Ecton they do indicate the extraction of copper minerals and the circulation of metalwork in the vicinity of the Early Bronze Age mines. Drawing on the corpus of evidence for primary metallurgy elsewhere in Britain and Ireland, the historical context of the Ecton Mines and the available information on the Early Bronze Age in their hinterland, this chapter outlines the methodology employed in the program of original fieldwork. Following on from Doonan (1994; 1998) and

O’Brien (1998) the programme of fieldwork involved the active investigation and field survey of a copper extraction site.

In many regions of Europe the evidence of copper production has appeared in close association with the exploited mineral deposits and can be considered a highly visible component of the archaeological record (Doonan 2008). This is not, however, a universal trend and the emerging evidence for metal making on the Iberian Peninsula and in the earliest stages of the alpine region appears divorced from the mineral deposits and has a closer association with habitation sites (Krause 2009; Rovira 2002). Evidence from Ross Island (O'Brien 1995; 2004) presents the earliest Irish copper metallurgy as a coherent whole, with the complete process from extraction to smelting present within a very confined space. However, this pattern is not repeated at sites in Britain where survey and excavation of the copper mines and their immediate surroundings has been limited not been undertaken in many cases beyond the identification of the site itself. As such, these investigations have not recovered even cursory evidence for the transformation of ore to metal (Bannerman 1992; 2000; Blick 1991; David 2000; Doonan *et al.* 2001; Doonan and Eley 2004; Dutton 1990; Dutton and Fasham 1994; Gale 1989; Jackson 1968; 1984; James 1990; Jenkins 1995; 2003; Lewis 1994; O'Brien 1994; Timberlake 1990; 2003; Timberlake and Prag 2005). The site of Pentrwyn on the Great Orme headland is an exception that was identified during work in advance of the widening of the adjacent roadway (Chapman 1997).

The fieldwork at Ecton will take advantage of the high potential for the recovery of evidence relating to copper smelting in the face of later exploitation and site development. The steep gradients and topography of Ecton Hill led to the development of internal structures to facilitate the removal of ore and mining waste initially through Dutchman level on a mid slope terrace (Barnatt et al. 1997), and as the development of the mines continued at the level of the valley, through the Deep Ecton Adit, Salt’s Level and Apes Tor Level (Barnatt 2002; Porter and Robey 2000). The removal of the mining material at this lower level resulted in the accumulations of later mining debris forming away from the earlier workings and spoil on the higher slopes of the hill. If the transformation of ore to metal was carried out in the vicinity of the mines in the Early Bronze Age then there is high potential that this evidence will remain on the upper slopes of Ecton adjacent to the Bronze Age workings.

Fieldwork also extended beyond the immediate vicinity of the mines into the surrounding Peak District in an attempt to situate the mineral extraction site within the other remains of the Early Bronze Age landscape. Ecton Hill is surmounted by a number of Bronze Age barrows that connect the mines to other Bronze Age activity and to a palimpsest of archaeological remains extending to activities beyond primary metallurgy (Barnatt and Smith 1997b). These remains are dominated by barrows (Barnatt and Collis 1996), which have a primarily funerary association, but which were used to assess the perceived importance of the copper resource and its significance in the creation of an inhabited Bronze Age landscape. Owing to the scale of the potential landscape to be interrogated regarding the catchment area from which resources may have been drawn and the extent of metallurgical activity, a nested landscape approach was adopted.

5.2. A Nested Landscape Approach

The adoption of a nested landscape approach is a response to the difficulties in defining an appropriate and adequate survey area within such a large region inhabited by a population that may have been at least partly mobile (Honeychurch et al. 2007), or inhabiting parts of the landscape on a seasonal basis. Early Bronze Age populations within the Peak District have been previously described as at least seasonally mobile with flexible scales of social organization and interaction (Kitchen 2001). Whether all or parts of the population was indeed mobile through at least part of the year or not, the scale of the proposed area and dearth of evidence for habitation or settlement present problems in defining appropriate survey parameters. A nested landscape approach creates different scales of survey by applying different survey resolutions and knowledge of site locations within a given area (Honeychurch et al. 2007). By applying different resolutions at increasing scales, field survey can be more integrative and move beyond the limitations imposed by a single site survey without loosing focus on specific features or forcing a more general approach to the landscape. Employing a nested landscape approach allows the investigators to engage with a wider potential study area and relate possibly interconnected sites through the evidence of associated activities, the presence of certain materials or other factors depending on the landscape, such as inter-visibility in a visually restricted area.

Turning to the fieldwork at Ecton, the copper mine is one aspect in the production of copper that has been located in both time and space. It therefore presents itself as an obvious initial target area for fieldwork. As previously indicated, the development of the later mines at Ecton mainly focused on the lower part of the hill and the adjacent Manifold Valley. This has preserved parts of the Early Bronze Age mining landscape the higher slopes. This kind of preservation may relate to a higher potential for the recovery of evidence relating to post extraction processes in the vicinity of the Bronze Age mine workings. Therefore the highest resolution survey took place in the vicinity of the copper extraction site on Ecton Hill. This was done using a combination of geophysical and geochemical survey techniques that were prefaced by pedestrian survey.

The copper mines do not exist in isolation, but are one resource, representing one site in a landscape that was inhabited by a mobile Early Bronze Age population. This informs the project in two ways. Firstly, as seen in chapter three, the *chaîne opératoire* requires the input of a number of materials, which may have been sourced from within the hinterland of the mines. By employing a nested approach it was possible to expand survey into the wider landscape to identify the availability of potential resources, which may have been integral to the tasks of mining, beneficiation and smelting copper ore. The second way in which the wider landscape is utilized is through the traces of the Early Bronze Age landscape still existent within the hinterland of the copper mines. By situating the mines within these other archaeological sites it becomes possible to identify Ecton as more than a site of activity, but as part of a coherent inhabited landscape. By using a nested approach it remains possible to engage with these multiple aspects of the landscape without sacrificing the detail of specific resource locales or the potential relationships between different sites.

Therefore the nested approach employed in the fieldwork undertaken at Ecton and in the surrounding landscape examined an increasing area with different resolutions. The initial and most intensive scale examined the potential for post extraction processes in the immediate vicinity of the mines. These processes potentially involved any stage from the crushing and hand sorting of the extracted ore and the heat altering or smelting of the ore to metal. A second level focused on the landscape of Ecton Hill. This level was concerned with the identification of additional sites relating to Bronze Age activity in proximity to the copper mines. A third level expanded to the surrounding landscape and sought to identify the potential for additional resources, copper mineralization and other materials involved in the metallurgical chaîne opératoire. It is at this level where the other archaeological sites and the impact of the copper mines on the creation of space within the landscape were also considered. This level incorporated both field and map based survey and utilised GIS mapping software to elucidate possible relationships between sites within a five-kilometre radius of the copper mines on Ecton Hill.

5.3. Geophysical and Geochemical Survey: Intensive Local Survey

One of the major assumptions that inform archaeological narratives of early metallurgy is that the initial making of metal was likely conducted in the immediate proximity of the ore source. This assumption can be considered a holdover from systems archaeology (Watson et al. 1971) where models based on the efficient use of time and energy were used to predict the most likely boundaries and locations of specific activities informed by the distribution of resources. A number of case studies have produced evidence to support the direct association of copper smelting with mineral outcrops (c.f. Doonan 1999; Lupu 1970; Milton et al. 1976; Rothenberg 1974). However this model cannot be applied as a general principle to practices within diverse regions and landscapes without considering the environment in which mining was conducted. Whereas some environments or settings may not have provided necessary space or support for an entire community, necessitating the establishment of activity specific mining camps, other settings may have been more attractive for settlement.

Evidence from Ross Island in South West Ireland (O'Brien 2004), lends further support the direct association of mineral extraction and copper production. However, the location of smelting activity is not always immediately proximal to the ore source. Evidence from a number or early mines in Europe and the Near East shows that mining and smelting were discrete activities (c.f. Bassiakos and Philaniotou 2007; Catapotis 2007; Doonan and Day 2007; Hanks and Doonan 2009; Kienlin and Stöllner 2009). The pattern found at Ross Island has not been repeated at sites in Britain. This may be in large part to the limited survey and excavation at known sites within England and Wales. The only known smelting site in Britain, at Pentrwyn, is located at some distance from the known mines on the Great Orme Headland in North Wales [roughly 1km] (Chapman 1997; Jones 1999), although the ore may have come from a closer ore source for which exploitation has not yet been established.

The Geophysical and geochemical survey on the Ecton hillside in the vicinity of identified mining features was one part of the English Heritage funded Ecton Hill Project. This project consisted of three individual aspects that were: the visual survey and mapping of the mines, both terrestrial and subterranean; the excavation of the mine, which focused on the earliest mine openings and associated features; and the geophysical and geochemical survey of the hill side in search for additional activity areas, which if identified would include excavation. Each of these three areas was undertaken in partnership by different project leads. The survey and mapping of the Ecton Mines was led by Peak District archaeologist John Barnatt, the excavation of the mine entrances and additional features was led by Simon Timberlake and the Early Mines Research Group, and geophysical and geochemical survey was conducted by the University of Sheffield and led by the author, Ryan Eldridge, under the guidance of Roger Doonan, his academic supervisor, and geophysical specialist, Colin Merrony. This third part of the project was designed to investigate the possibility that copper processing and smelting was conducted at this site in the immediate vicinity of the ore source. This is the highest resolution survey within this thesis. It employed a combination of geochemical and geophysical survey methods in a tightly focused target area among the remains of Bronze Age mining activity. Prior to defining the survey parameters used for the geophysical and geochemical survey, a pedestrian survey of the mining features was conducted. While this initial visual survey failed to identify evidence of beneficiation or smelting at the surface, it was used in conjunction with pre-existing research to define the target areas for more intense survey.

The identification of surviving Bronze Age mining features were at Stone Quarry Mine and the Lumb (Barnatt Forthcoming; Barnatt *et al.* 1997; Barnatt and Thomas 1998; Bray and Horsley 1998; Doonan 1998), defined the primary target area. Stone Quarry mine is located on the flatter north shoulder of the hill while the opencast like 'Lumb' feature cuts down the steep northwest slope from the brow of the hill, just below one of the surmounting barrows. Sampling grids for the geophysical and geochemical survey were chosen to cover a wide range of environments encountered on Ecton Hill and avoided areas that had been subject to modification during the post-medieval phase of mining, such as the surface beyond Dutchman Level. Both geophysical and geochemical surveys were conducted on the same grid areas.

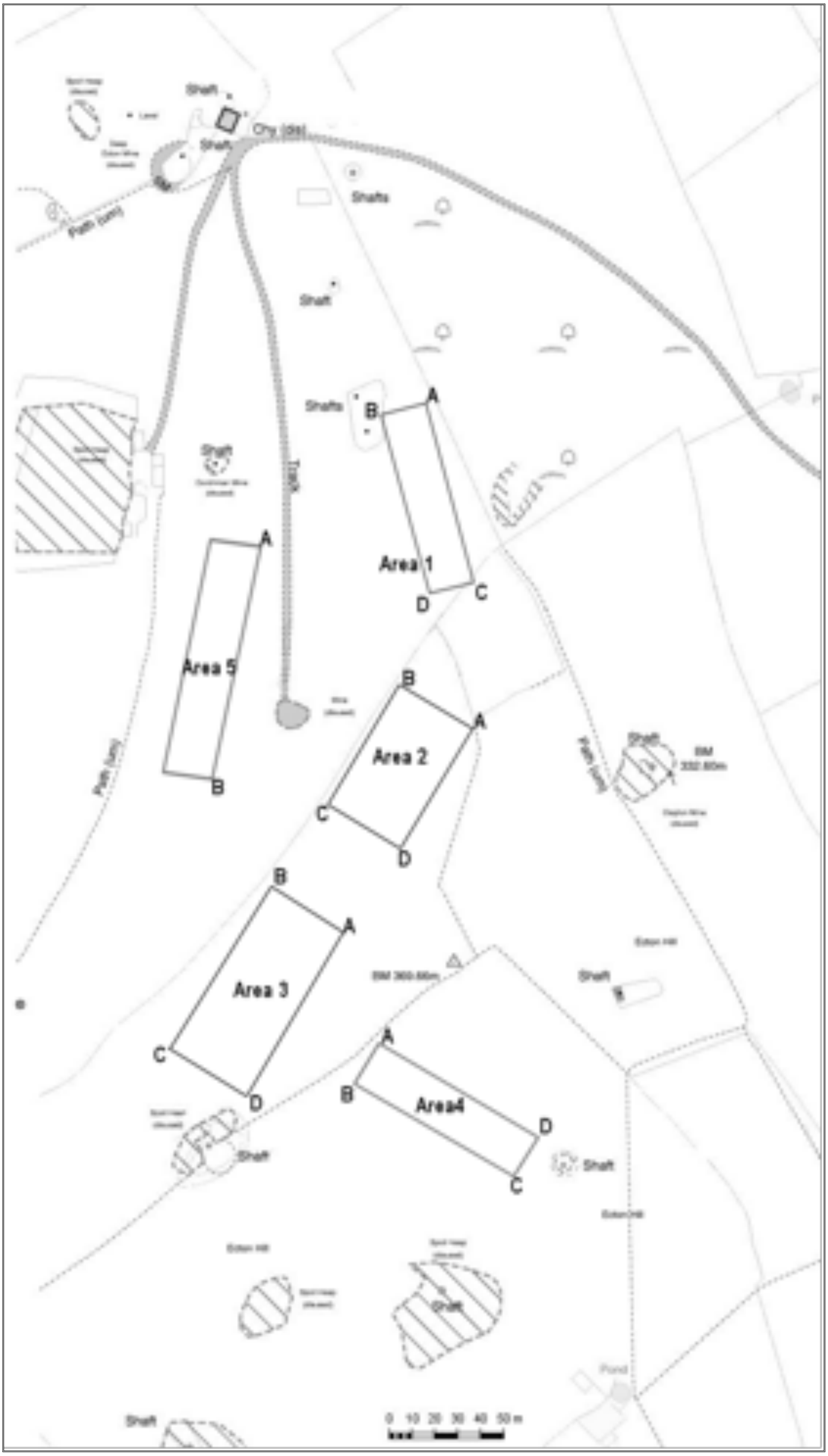
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Figure 5. 1 Map of Survey Areas 1-5

Area 1

Area one is spread along the northern flank of Ecton Hill from Stone Quarry mine up towards the boundary wall. This area covers four 20x20m grids for a total survey area of 20x80m and extends the area surveyed by English heritage in 1998 to the southeast (Bray and Horsley 1998). Stone Quarry Mine, at the northern end of area one, is among the earliest reported mines on Ecton Hill and is a promising candidate for prehistoric mining activity.

Area 2

Area two is located on the sloping ground to the northeast of another suspected prehistoric mining feature known as 'The Lumb'. A total of six 20x20m grids were surveyed resulting in a total grid area of 60x40m for area two. This area also included part of the area surveyed by the English Heritage Team in 1998 (Bray and Horsley 1998). A portion of area two had also previously been subjected to geochemical survey (Doonan 1998). The results of these previous surveys were a factor in the location of this survey grid.

Area 3

Area three is adjacent to area two and is again located on the sloping ground in proximity to the feature known as 'The Lumb'. Area three covers a total of eight 20x20m grids to the southwest of the Lumb for a total grid area of 80x40m. No previous geophysical or geochemical survey had been conducted in this area.

Area 4

Survey area four covers a total of four 20x20m grids extending southeast from the brow of Ecton Hill, away from the trig point surmounting a barrow atop the hill. Area four covers a total area of 80x20m over reasonably level ground.

Area 5

The Grid in area five extends roughly north – south covering five 20x20m grids. This survey area is on the northwest slop of Ecton hill immediately below Fly Mine and covers a total area of 100x20m.

Area 6

This area is due north of the Ecton Pipe shaft and the converted remains of the engine house and is the largest single area where both geophysical and geochemical survey were undertaken. It covers a total area of just under 160 x 120m on the northern flank of the hill encompassing 50 20 by 20 m grids. No mine openings are found within this area; however this is the largest open area on the northern side of the hill. This area features a relatively level surface with a comparatively gentle slope extending to the north, prior to a significant drop. This final survey grid aims to include the area where examples of fused ore were reportedly collected in the vicinity of the remains of the "Deep Ecton engine house" (Kirkham 1947: 63), although no such material remained in evidence at the time of pedestrian survey conducted in advance of the geophysical and geochemical survey.

5.3.1. Geophysical Survey

The unique geological and environmental conditions at Ecton presented an opportunity to employ both geochemical and geophysical prospection aimed at identifying production sites' (Doonan 1998). The smelting of copper minerals is conceptualized as a process that relied on elevated temperatures within a small controlled environment such as a ceramic or stone built structure. Such pyrotechnical features leave a distinct magnetic signature that is detectable using magnetic survey methods. By using a magnetometer-based survey these features would be visible as discrete dipoles against the background of the limestone hill. If such burning was associated with the heat alteration of copper then one would also expect to see elevated levels of copper in the soil matrix (Doonan 1998). The method incorporated a campaign of excavation to ground proof anomalies and test excavations were carried out at locations where both survey methods indicated a high potential for pyrotechnic and metallurgic activity.

The primary geophysical survey technique employed on Ecton hill was magnetometry. Magnetometry was considered the most suitable method for this survey because of its ability to detect the thermo-remnant signatures expected of metallurgical features. A Geoscan FM36 magnetometer was used to collect magnetic data at 0.25m intervals from survey lines separated by 1m within 20m grid squares. When working on steep gradients the survey was orientated so that it could be traversed perpendicular to the slope. Due to the difficult topography survey was undertaken with the use of the hand trigger. Other methods of survey may also have been suitable at this site; however, magnetometry presented the option to focus on specific types of magnetic signature in the interpretation of the survey results, such as a dipole that may indicate intense heat, and was chosen to minimize the potential interference from the remains of post-medieval activity (Gaffney and Gater 2003). Magnetometry provided the best possible resolution in differentiating between different magnetic features. Alternate methods, such as magnetic susceptibility, can provide a tighter resolution and are more adept for defining sites and features after the have been identified. Magnetic susceptibility requires close proximity to the target sample, as it need to expose it to an external magnetic field, whereas magnetometry measures the variation in the earths own magnetic field, meaning buried features can be detected above the surface (Gaffney and Gater 2003).

5.3.2. Geochemical Survey

Geochemical survey was performed on site using a Niton XLT hand-held portable x-ray fluorescence (pXRF) analyser. Soil cores were taken using a purpose-built corer with a 6cm diameter. The face of the sample was dressed using a sharp blade to provide a suitable surface for analysis. All cores were removed from the corer with care taken to avoid compression of the core sample. Each determination was made in the B-horizon or in the lower portion of the A horizon where the B-horizon was not attainable (this was rare). Analysis times were determined to be most appropriate at 30 seconds, which allowed satisfactory results at the highest sampling resolution. Calibration and standard checks were undertaken periodically throughout the survey to monitor drift and contamination. Geochemical survey employed multi-element analyses including copper, nickel, lead and tin; however, only copper is presented here.

The potential for geochemical survey by portable XRF has been demonstrated by the limited surveys at the Great Orme (Wager et al. 2002) and on the Isle of Man (Doonan and Eley 2000), but is still experimental for this kind of field survey. This type of geochemical analysis cannot differentiate between natural concentrations of elements, such as leaching from accumulated mine spoil, and activity specific concentrations, such as the concentration of copper ore through human intent, but the belief was that by coupling the geochemical techniques with the geophysical techniques outlined above, the survey would produce complementary data and be more likely to pinpoint areas of specific activity. High temperature processes leave a detectable magnetic signature, whilst areas of copper processing concentrate the presence of copper and enhance the background copper levels. Thus areas associated with both high magnetic response and elevated copper levels can be presented as good candidates for potential copper smelting sites.

The work done at Ecton will build on these studies, and on the initial geochemical survey undertaken by Doonan in 1998 and will assess the advantages of portable XRF technology. The Ecton study represents the first prehistoric mineral extraction site where extensive high-resolution geochemical mapping has been conducted and its combination with traditional geophysics will allow for its evaluation as a field methodology.

5.4. Pedestrian Survey of Ecton Hill

Ecton Hill is a prominent limestone hill within the White Peak, but is situated in a location that lends itself to the exploitation of resources from many environments in both the white and dark peaks. The well known copper and lead ores of the hill were the target of post-medieval adventure miners prior to their exploitation by or

on behalf of the owners of the land and or mineral rights. This period of activity had a significant impact on the hill and adjacent Manifold Valley including the erection of buildings, delving of mines, shafts and galleries and creation of roads and access.
The second area of survey targets the entirety of Ecton Hill. A pedestrian based visual survey was undertaken, which focused on identifying previously known and reported mining features, such as shaft openings as well as identifying any other potential mine workings, and the known Bronze Age barrows. It also targeted any surface evidence relating to the practice of primary metallurgy such as accumulations of slag or crushed copper minerals that may denote a working area. Survey in this area also sought to identify potential resources, such as clay and sand deposits, that could be used in the construction of smelting 'architecture'.

Pedestrian survey was undertaken on random 25m transects covering the top of Ecton, the eastern and western ridges and the significant valley on the south side of the hill that descends to the bottom of the Manifold river valley. Increased focus was given to the vicinity of the barrows on the western ridge of Ecton Hill overlooking the mines. This pedestrian survey of Ecton Hill employed an integrated methodology that incorporated elements of a phenomenological approach to the landscape (Tilley 1994) and a *chaîne opératoire* approach in the common experience of the human body. This is not a true phenomenology of the landscape, which, whilst having been instrumental in dissolving artificial culture/nature dichotomies, has also been criticized for lacking critical reflection or rigorous observation (Fleming 1999; Fleming 2005). Rather this was sought as a means to understand the articulation of archaeological features in relation to each other or to natural features (c.f. Cummings and Whittle 2004; Tilley 1994), and the potential routes or pathways available to an individual wanting to access the site of the mines on the north-western slope of Ecton. It provided insight and impressions of traversing through different pathways in terms of visibility, knowledge of landscape and the difficulty, or ease of moving materials to and from the site.

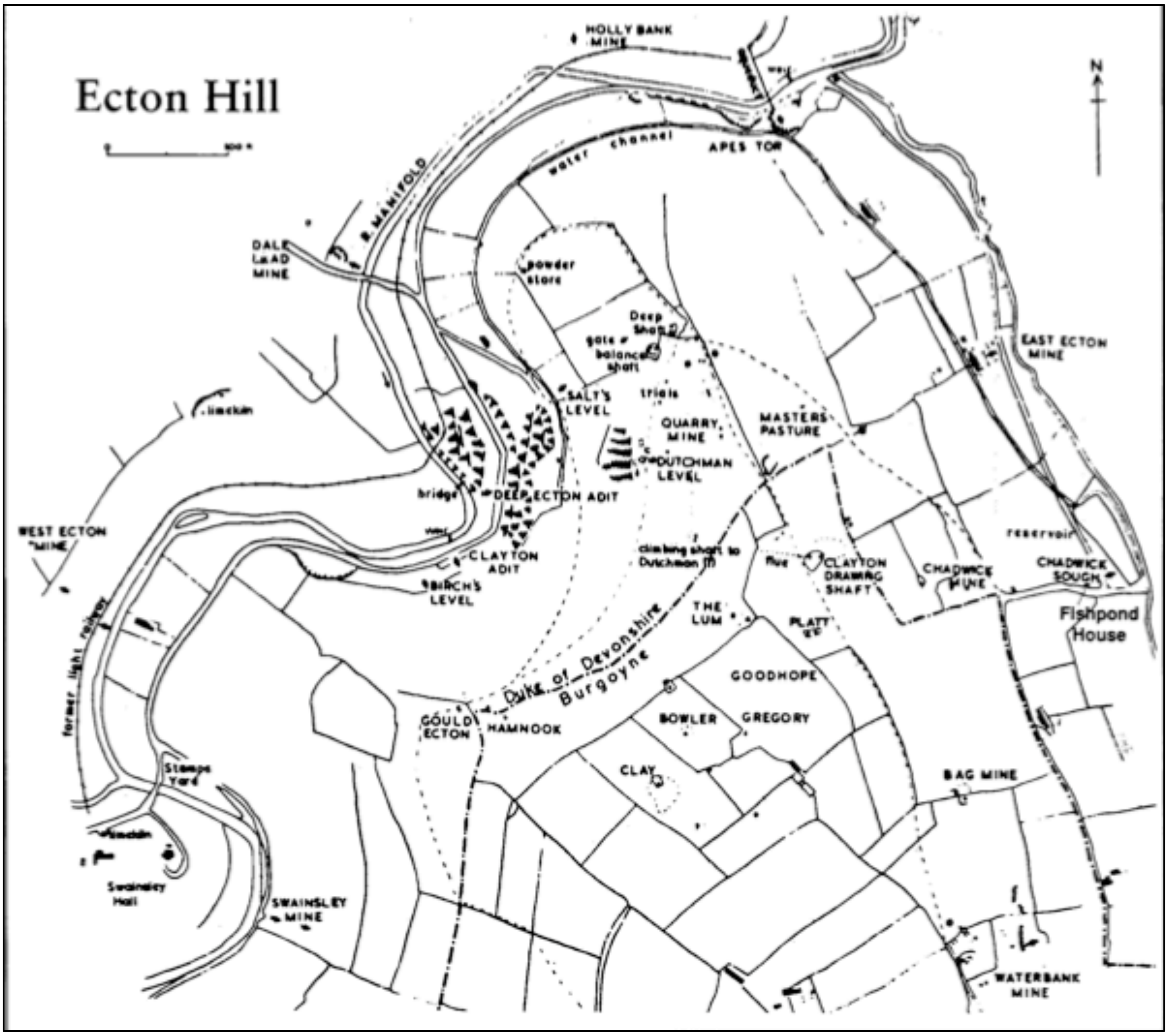

Figure 5. 2 Map of mines on Ecton Hill [figure 4.2] (after Porter and Robey 2000)

The adopted principles that underlie a phenomenological approach are that the archaeological record cannot be understood in the absence of human activity, that meaning arises through the human engagement with material conditions, and that the body is the medium through which this engagement occurs (Barrett and Ko 2009). This is a means of attempting once again to investigate the landscape as a dynamic stage in which people moved and possibly participated in a range of activities. The inhabitants of the Bronze Age who moved through this landscape encountered environmental and topographical conditions with witch they had to contend and which may have impacted the use or perception of space. These conditions and the subsequent use of space may have imparted to Ecton a specific sense of place that may have been brought out further through subsequent activity or landscape modification. Where possible observations will be directly linked, at least in part, to other means of inquiry, such as viewshed analysis using a GIS platform.

5.5. Ecton within a Bronze Age Landscape

The third stage of the nested approach considers Ecton within a wider landscape. This stage incorporates field survey with desk-based survey and GIS analysis. This stage covers an area with a radius of roughly five km centred on the mines at Ecton Hill. Field survey was targeted using the desk-based research, on possible resource outcrops, including: copper mineralization, clay deposits, and watercourses. Areas where these resources intersected were considered to have higher potential for the recovery of evidence relating to metallurgical or Bronze Age activity. GIS analysis was used to map known later Neolithic and Early Bronze Age sites

5.5.1. Desk Based Survey

This desk-based survey is intended to inform further fieldwork as well as map potential resources beyond the survey area than may have been drawn upon in the quest for copper metal in the Early Bronze Age . The potential resource pool from which Bronze Age inhabitants could draw was not physically limited to the immediate vicinity of the known copper mines, but, may have spanned a considerable distance. This macro level survey sought to identify geologically significant outcrops in the region surrounding Ecton Hill. This included additional outcrops of copper ore, and accumulations or deposits of quartzite cobbles that were the likely source of hammer stones at Ecton. The quartzite cobbles employed at Ecton are not a local resource and likely represent an exotic material that was brought into the region from Triassic deposits on the borders of the Peak District, the origin of which is primarily Carboniferous; however they may have been locally available in the major rivers in the vicinity of Ecton. The possibility that they were available in the river system of the southwest peak district was tested in field survey.

The mineral deposits of Ecton are not the only ones that have been exploited in this region. A number of other small-scale mining operations exploited other deposits of copper and lead during the post medieval period (c.f. Porter and Robey 2000). While the only other positively identified Bronze Age copper mine in England is found at Alderley Edge, just beyond the borders of the Peak district on the eastern edge of the Cheshire Plain, this does not preclude the surface exploitation of additional outcrops that may occur in the Hamps and Manifold region. The Identification of a possible hammer stone among later mining remains at Long Low, near Wetton may indicate additional albeit ephemeral mining activity in the region or the further processing of ores at some distance from the mines at Ecton (Howarth 1899; Pickin 1999). Possible mineral outcrops were identified during this desk-based survey, from geological maps and mining records and, where possible, were identified in the field

The final task associated with this desk-based survey was to plot additional field survey to be undertaken within the landscape surrounding Ecton Hill. This third stage of field survey took place within a roughly defined landscape within 5km of the copper mines on Ecton Hill. The desk-based study was used to identify specific target areas and resources within this landscape that may have been a part of the metallurgical taskscape.

5.5.2. Field Survey

The field survey undertaken as part of this wider resolution stage took place within a landscape defined by a five km radius of the mines on the northwest slope of Ecton Hill. Expanding the landscape survey to this area meant that it included a range of different environments and ecological zones that are found in proximity to the Bronze Age copper mines. A total area of almost 79km^2 falls within this zone and as such a targeted approach was needed, which was informed by the preceding desk-based survey.

This level of survey is meant to address the possibility that other resources, or more appropriately the confluence of more than one resource, drew the smelting process away from the source of the ore. Fuel may have been a major concern and resulted in the dispersal of metallurgical activities (Gale and Ottaway 1990). The potential use of fire setting would have consumed timber in the mining process. If woodlands were restricted in the immediate vicinity of the mines, smelting activity, which depended on the same resource for in the making of charcoal for fuel, may have been conducted at a discrete distance so as not to over exploit limited timber. Surviving woodland is not likely to be representative of forestation in the Bronze Age and palaeoecological data is not currently available for this region. Field survey therefore focused on other resources.

Deposits of clays and sand are important because of their potential role in the *chaîne opératoire* of metal production. The location of such deposits within the search area may have provided alternate sites for stages in the metallurgical process. Because of the confluence of metallurgical activity with a water source observed at other sites (Eibner 1993; Kassianidou 1999; O'Brien 1994; Ottaway and Wager 2000; Timberlake 2003; Wager 1997), focus was directed at watercourses, including rivers, streams and springs, which flow through the survey area. Areas where clay or sand deposits and watercourses intersected were viewed as high priority targets as these areas were a confluence of multiple resources that may have been important in the smelting of copper.

Survey transects conducted along water ways were aimed at identifying the remains of copper production visible at the surface or in the eroded channels; however, it also made possible a survey aimed at identifying the potential occurrence of quartzite in the catchment area. Standard 25m transects were walked along the banks of watercourses and focused on the eroded channels where they were visible. These transects were aimed at the identification of features or material relating to the processing or smelting of copper ore. Any metallurgical debris was collected excepting from locations associated with post-medieval processing and smelting along the Manifold River. As part of the same survey transects were also surveyed along exposed fluvial deposits. This aspect of the survey sought to identify the occurrence and ratios of quartzite amongst the river born sediments. These transects were determined by the length of the fluvial deposits. During the summer of 2010 the River Manifold ran dry from Wetton Mill to the southern boundary of the survey area. Twenty-five metre survey transects were walked the length of the dry riverbed.

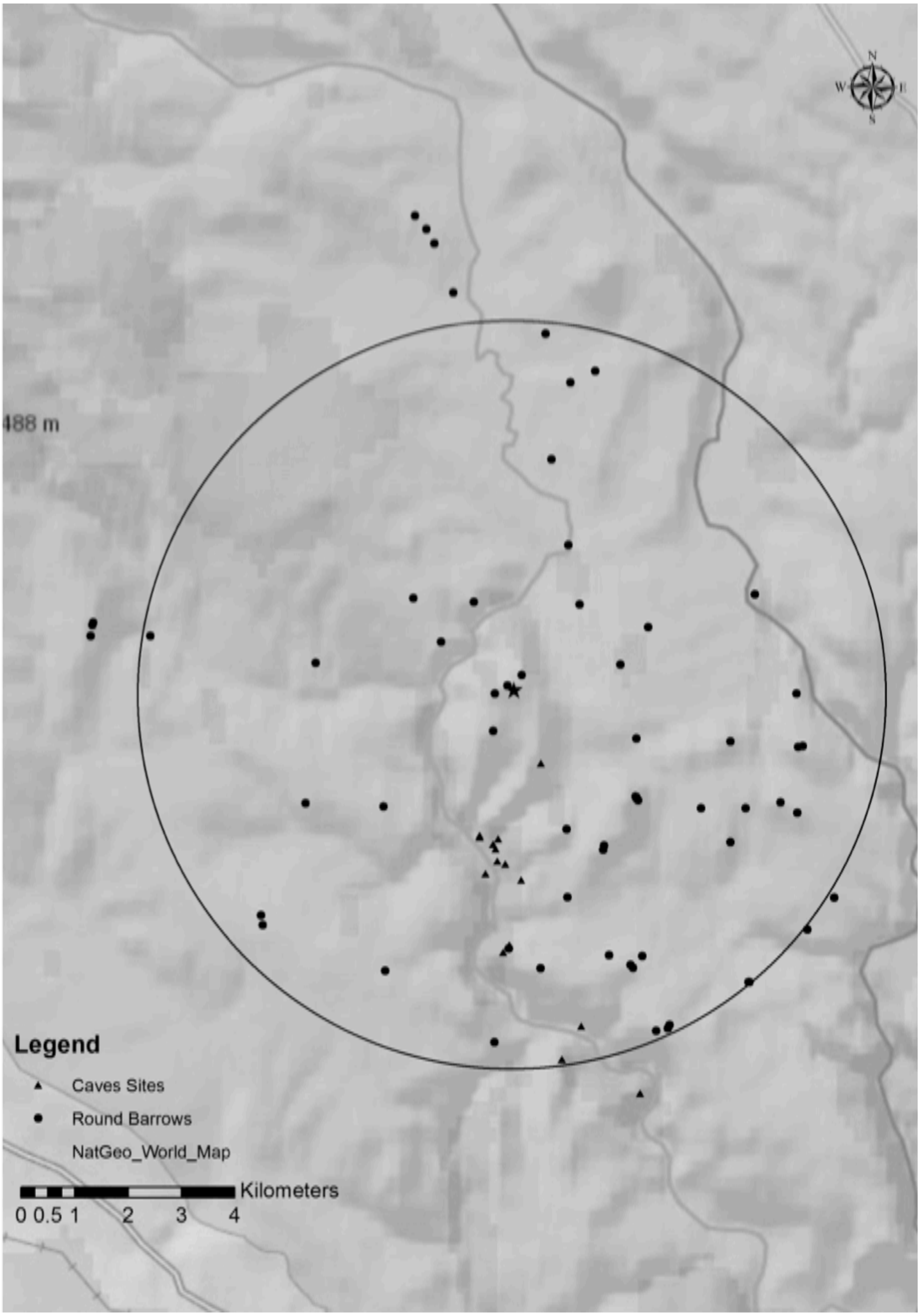

Figure 5. 3 Map of the Stage Three survey area showing approximate boundary

5.5.3. GIS Based Analyses

With the relative paucity of evidence for Early Bronze Age activity in Britain an integrative approach should engage with as much of the potential information on the Early Bronze Age landscape as possible. Therefore this thesis includes GIS based analysis of the landscape using the distribution of Bronze Age remains in the hinterland of the Ecton copper mines. The use of GIS in Archaeology has become widespread and it is a popular format for storing and visualizing geographical information. Most of the currently available Geographic Information Systems include searchable databases of spatially referenced features, such as sites or finds, associated with a series of non-spatial attributed such as period or material. GIS programs also feature a map-based interface that is capable of displaying spatial data and a collection of analytical routines to interrogate the database or perform other functions to create new information (McElearney 2007). The use of GIS programs provide a method of questioning the data to generate new information on the distribution of sites or specific artefact types or to analyse the location of sites, finds, and monuments in relation to other factors (McElearney 2007).

Initial criticisms of GIS based analyses were focused on the use of this type of analytical software as a tool for predictive modelling within a systems archaeology paradigm. It has been employed to assign correlations between archaeological sites and environmental factors in an approach that was both fundamentally reductionist in nature (Gaffney and van Leusen 1995; McElearney 2007) and could be argued to support models of environmental determinism in archaeological interpretation (Gaffney et al. 1995; Gaffney et al. 1996; Llobera 1996; Wheatley 1993; Wheatley 2000). GIS programs produce simplified representations of Cartesian space (Brück 2005; Wheatley 2000), which has tended to present the landscape as neutral, devoid of meaning, onto which archaeological remains can be mapped. It was therefore deemed possible to understand the inhabitation of a landscape simply through a distribution of sites (Wheatley and Gillings 2002). However, the inhabitation of landscape is more nuanced. The landscape, like objects, has its own characteristics with which people interact (Gosden 1994;

Jones 2002). The landscape in neither neutral nor passive, but both shapes and is shaped by human experience; spaces are socially created and through interaction given meaning (Barrett 1994; Bender 1993; Ingold 1993; Thomas 1993).

The use of GIS software enabled the analysis of the landscape from two different but complementary angles. View-shed analysis was employed to test inter-visibility at Ecton, amongst the hill and the numerous barrows in the surrounding landscape. It also focused on the possible importance of inter-visibility between the barrows surrounding Ecton and those atop the hill. The second approach plotted the deposition of different material classes and so was also heavily informed by the distribution of barrows. Both of these approaches are intended to elucidate the relative importance of Ecton Hill, and its copper ore, within the landscape. Both of these analyses were performed using the ArcGIS software package.

Mapping the distribution of sites and finds first required the creation of a codified database. This was based on the excavations that have been conducted within the survey area over the last two centuries. As noted in the previous chapter, the Peak District is a palimpsest of archaeological features ranging from lithic scattered to field systems. The Early Bronze Age remains are dominated by barrows, which have a primarily funerary association (Woodward 2000). Antiquarian interest in this area of the Peak District resulted in the excavation of several of the barrows on both the White and Dark Peak during the 19th century (Bateman 1848; Bateman 1861). While the work of Bateman was biased towards the remains of the White Peak, his contemporary, Carrington, excavated barrows on both the limestone hills and moorland surrounding Ecton Hill (Barnatt and Collis 1996; Bateman 1861). This has been augmented through the work of Peak District Archaeology (Barnatt 1996a) and as a result there is greater balance of archaeological excavation within the survey area.

The first of two analyses carried out using the ArcGIS software package relied on a database of all excavated barrows showing the absence or presence and quantities of specific material classes and numbers of internments and cremations found within the Bronze Age barrows. Materials were divided into classes including metals, lithics, Faunal remains, ceramics, internments, cremations and special deposits, which included things like a sandstone vessel and jet beads. These were then plotted using the ArcGIS program. The deposition of material is a socially informed practice and variations in the distribution and compositions of barrows provide an insight into interactions with the landscape and the creation of meaningful space. Therefore the identification of such variation through GIS analysis can be used to demonstrate how Bronze Age communities differentiated space and imbued places with different meaning. This spatial analysis will highlight any specific regions within the study area that present higher concentrations of any specific materials within barrows. This analysis is aimed at identifying any areas within the survey region that may show significantly different depositional practices that may reflect the different use of space.

The second GIS based analysis was a viewshed analysis. This is a standard analytical tool employed in landscape studies that allows the inter-visibility amongst sites to be digitally evaluated and characterized. This analytical tool demonstrates which areas of the landscape are visible from a specific point or points when combined with an elevation model of the landscape (McElearney 2007). The elevation model is typically an array or a grid of height values taken at fixed intervals, known as either a Digital Elevation Model [DEM] or a Digital terrain Model [DTM] (McElearney 2007). GIS based view-shed analysis has been criticized on its inability to account for variables that may obscure visibility such as vegetative cover and distance (McElearney 2007). Vegetation, specifically tree growth, can have a significant impact on the visibility of sites and past landscape modification may have involved selective deforestation to facilitate or obscure the view from or between specific locales. The identification of such factors remains difficult and while it can to some degree be mitigated using palaeoenvironmental studies, it cannot be wholly resolved (Tcschan et al. 2000). Without available palaeoenvironmental data within the target landscape this remains an unresolved issue and the view-shed represents an idealized visibility.

A digital distribution of sites is, as noted above, a fairly simplistic representation of the landscape and does not account for limitations in visibility based on distance. Sites or objects may not in fact be visible, despite the existence of a clear line of site, owing to scale or contrast over increased distances. The use of GIS software is also unable replicate knowledge based on familiarity with the landscape, which can provide increased resolution over greater distances. Populations familiar with a landscape may be able to reference more distant locations through the use of specific intermediary landmarks as a part of their seasonal round (Edmonds 1999), that are not immediately apparent to the uninitiated. The distance involved in this analysis is limited to only 5km, but issues of scale may still remain. Visibility will not rely on digital models, but will be confirmed in the field

Visibility may have held a central role in the construction of past landscapes and may have helped to inform the location of cultural features and landscape modifications (Wheatley and Gillings 2000). It may also have helped to inform the movement between or continuance of practice within specific locations (Wheatley and Gillings 2000). Important lines of visibility need not have been limited to sites and monuments, but may also have included other features, such as outcrops of specific resources or natural landmarks, or to socially defined boundaries; they could even be made in reference to environmental factors or other predictable phenomena (Wheatley and Gillings 2000). In order for the view-shed to be meaningful it must implicitly have had some social relevance in the past (McElearney 2007). The concept is not inherently new but has previously been used in discussions of territorial ranges (c.f. Fraser 1983; Renfrew 1979).

The viewshed analysis undertaken in the hinterland of Ecton examines the visibility of the archaeological remains on Ecton. The copper deposits are a natural yet encultured and socially significant resource, the origin of which was unknown to population that exploited it. Therefore access to the resource may have needed to be negotiated between several kinship groups that inhabited the region. This may have been done through expressions of kinship or descent vis a vie the creation of barrows, or through the expression of traditional access routes, demarcated by landscape modification. For the purposes of the view-shed analysis the copper mines on Ecton Hill and the barrows immediately above are considered a single entity or complex Early Bronze Age site. This allows the features of landscape to the south and east of Ecton, on the more visually restricted White Peak, to be incorporated into a meaningful investigation of their inter-visibility with Ecton.

The view-shed analysis was conducted using ESRI ArcGIS 9.3 software and the same database of sites as the preceding GIS method, with the addition of cave sites, such as Sycamore Cave and Thor's Cave. A single viewshed analysis was performed using the Bronze Age round barrow atop Ecton as the central point. The analysis of visibility and inter-visibility is designed to understand the importance of the mines, through their connection with the barrows atop Ecton Hill, within the wider landscape. This analysis is based on the hypothesis that higher inter-visibility between the barrows associated with the copper deposits with other barrows in the region emphasises the importance of the resource and community involvement in the creation of the associated landscape over individual control. The results of the view-shed analysis were tested in the course of field survey undertaken within this third stage of the nested landscape survey.

5.6. Material Analysis

Material analysis will be dependent on the material collected during fieldwork. All collected material will be subject to visual characterization. However, additional analysis will depend on the material and its context. Any recovered metallurgical debris will be subject to x-ray fluorescence to establish elemental composition in advance of additional analysis. If warranted, suitable metallurgical material will be sectioned and polished for micrographic characterization.

The collection of quartzite will depend on its prevalence within the survey area. If field identification is uncertain, suspect cobbles will be collected for later verification. Cobbles found in association with possible metallurgical remains will be examined for signs of use and may be collected for additional characterization.

If the occurrence of suitable quartzite cobbles within the survey area is uncommon more examples may be collected.

5.7. Summary

The geophysical and geochemical methods, used in the intense survey of the hillside immediately adjacent to the Bronze Age mines, provide the greatest potential for the identification of buried metallurgical activity. This combination of methods should be able to identify even the traces of a low or slagless method of copper production. While identified anomalies will be tested through excavation, the restriction of these methods to the immediate vicinity of identified mining features is a limiting factor. However, with no coeval settlement data or other activity it was important to employ these methods in a meaningful manner and for the highest potential recovery of evidence. Therefore, these methods were used to test the proposed model of copper production that posits the intimate physical relationship between mining and smelting. This fieldwork also aims to move the understanding of the early metallurgical process beyond a single site focus on the mine.

Ecton Hill is a distinct landform that looms over its surroundings. It hosts the traces of Early Bronze Age copper mining and a collection of possibly associated barrows. However, these remains have yet to be integrated with the palimpsest of archaeological remains in the wider landscape of the Peak District. The methods adopted for this fieldwork reflect the aims of an integrated archaeological approach to primary copper production in the Bronze Age. One of the founding tenets of this approach is to expand the focus of archaeological investigation beyond the extraction site and to situate the mines within an appropriate landscape. This provides a particular challenge amongst the ephemeral remains of a landscape that was likely inhabited by a mobile population. Without the benefit of understanding the patterns of habitation and activity in the Early Bronze Age , and in the absence of structures or settlements, situating the mines within coeval surroundings relies on the distribution of barrows, cave deposits, and find sites in its hinterland. A combination of field survey and GIS based analyses has been employed to provide some insight to the prominence and relevance of the copper mines within an encultured landscape. However, the highly impoverished remains relating to the activities of life impose limitations on the understanding of the landscape as an inhabited space.

The methodology used in the landscape survey is intended to approach an understanding of movement and exploitation through establishing the distribution of known resources, such as the quartzite cobbles. It is also aimed at identifying possible activity sites, indicated by accumulations of slag, vitrified ceramic, or crushed ore that will add to an understanding of metallurgical activity within the Early Bronze Age . The results of the desk based landscape assessment and GIS analyses are presented in chapter six, along with the results of the fieldwork, which includes the geochemical and geophysical survey and excavation. This chapter will also present the analysis of any materials collected in the course of fieldwork. The interpretation of the results and the implications for primary copper production in the vicinity Ecton will be presented as a case study as part of the discussion in chapter seven.

6. Results of Original Fieldwork and Analysis

6.1. Introduction

This chapter presents the results of the original fieldwork that focussed on the Bronze Age copper mines at Ecton and the surrounding landscape. Its presentation will mirror the format of the methodology chapter, and presents findings within the appropriate nested stages of investigation. The initial stage of fieldwork was undertaken as part of the Ecton Mines project, a collaborative project that involved an investigative team with members from the University of Sheffield, the Peak District National Park Authority and the Early Mines Research Group. The project aimed to advance the understanding of Bronze Age copper prospecting, mining and production, all issues that have been highlighted as under researched areas, particularly in England (English Heritage 1991). The initial stages of field survey followed the calls by O'Brien (1998) for the active investigation of copper production sites and Doonan (1994; see also Doonan and Hunt 1999) for the systematic field survey of copper extraction sites to further our understanding of the pyro-technologies associated with copper production.

Fieldwork also extended beyond the scope of the original Ecton Mines project and investigated the wider landscape within which Early Bronze Age copper metallurgy was situated. Drawing on observations from other Early Bronze Age metallurgical taskscapes from various regions of Europe along with the fragmentary evidence available in Britain, survey was expanded to encompass the hinterland of Ecton in order to consider the archaeological and environmental features that characterize this part of the Peak District.

6.2. Stage One: Intensive Local Survey

This first stage of survey was focused on areas thought to be associated with Early Bronze Age mining. These areas were associated with hammer stone finds and exhibited outcropping rock often with surface evidence of mining activity. The presence of outcropping limestone suggested that minerals might have been evident at the surface to early miners. These areas included Stone Quarry Mine and the Lumb, each with associated well sorted spoil, on the northwest side of Ecton Hill. Subsequent excavation of these features have confirmed both historic and Early Bronze Age mining activity (Timberlake et al. forthcoming). Prior to defining survey parameters a pedestrian survey was conducted of the hillside where these features are situated in order to determine parameters for higher resolution surveys. Ultimately six grids of varying size were established based on that pedestrian survey and pre-existing geophysical (Bray and Horsley 1998) and geochemical (Doonan 1998) evidence from the site.

6.2.1. Geophysical Results

The Geophysical method used at Ecton was a magnetometry survey, conducted using a Geoscan FM36 Fluxgate Gradiometer. Magnetometry was selected because it is particularly sensitive to magnetic enhancements in soil associated with high temperature activities. The steep and uneven terrain presented significant issues for survey traverses. For this reason survey was performed using the hand trigger, which had a significant impact on the rate of survey. The results of this survey are presented below by grid area. The magnetometer data was processed using GEOPLOT software. Areas of higher magnetism will appear as darker or lighter points within the overall matrix, depending on magnetic orientation. Strong magnetic anomalies will appear as visually distinct black and white points due to the sorting, or reorientation of the magnetic elements within the deposit or feature. This occurs in magnets and magnetized metals or specific ferrous objects where the magnetic alignment changes direction within the object, such as an angle iron, but is also indicative of high temperature processes. These same high temperature processes can also appear as a dark point with a white halo. Angular or odd shaped ferrous objects can also produce magnetic dipoles.

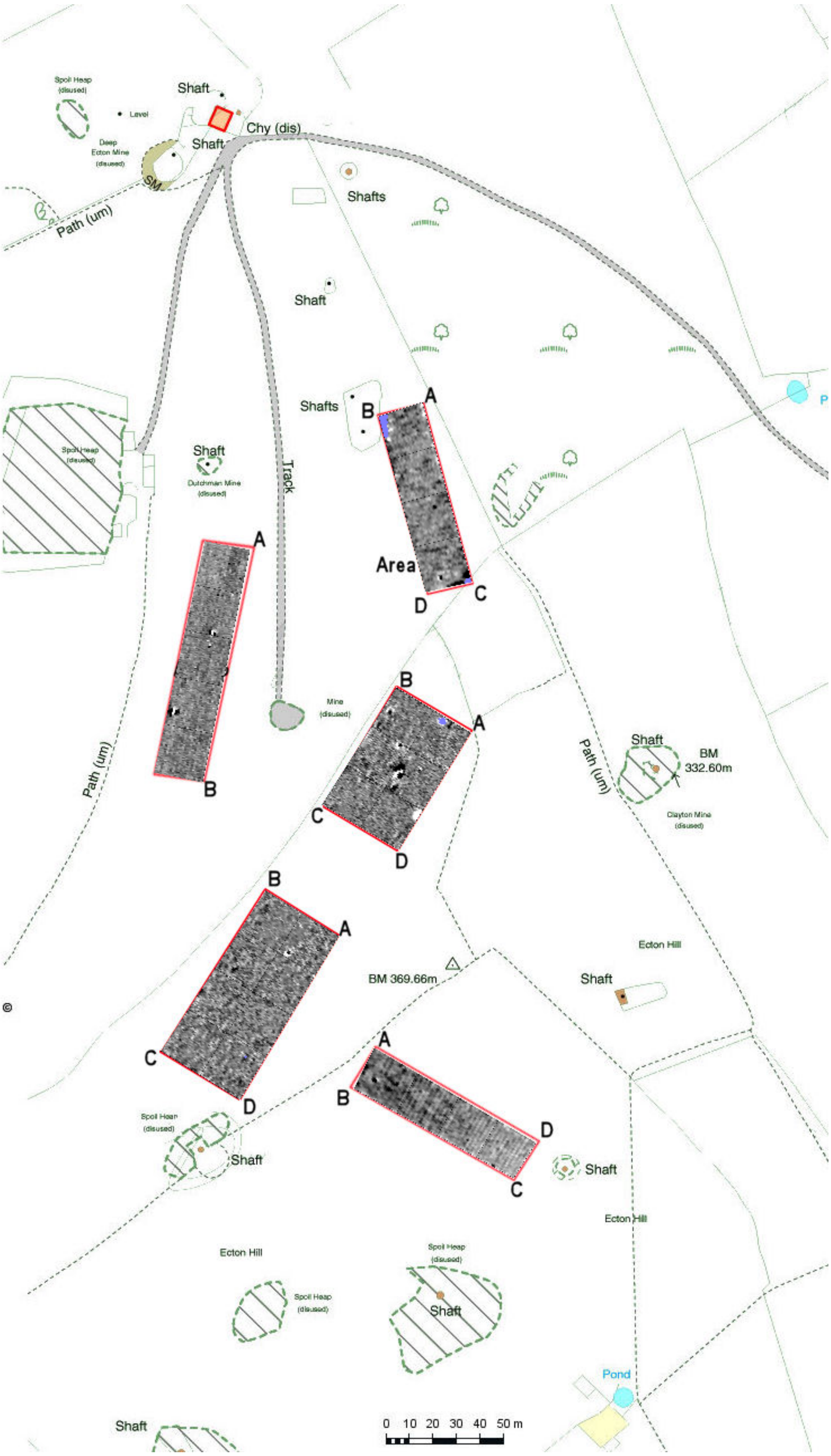

Figure 6.1 Survey areas of stage one showing magnetometer results

Area One

Area One extends along the northern flank of Ecton Hill (see Figure 6.2). This area is 20 metres by 80 metres and continues the area surveyed by English Heritage in 1998 (Bray and Horsley 1998) in a southeasterly direction. The only notable anomaly from this latest survey is the weak dipole anomaly in the most southeasterly grid (figure 6.3). This is located in close proximity to the wall and is associated with significant spoil heaps and mining activity. The ground is much disturbed in this area by spoil heaps and pitting and it is likely that this anomaly is associated with this activity.

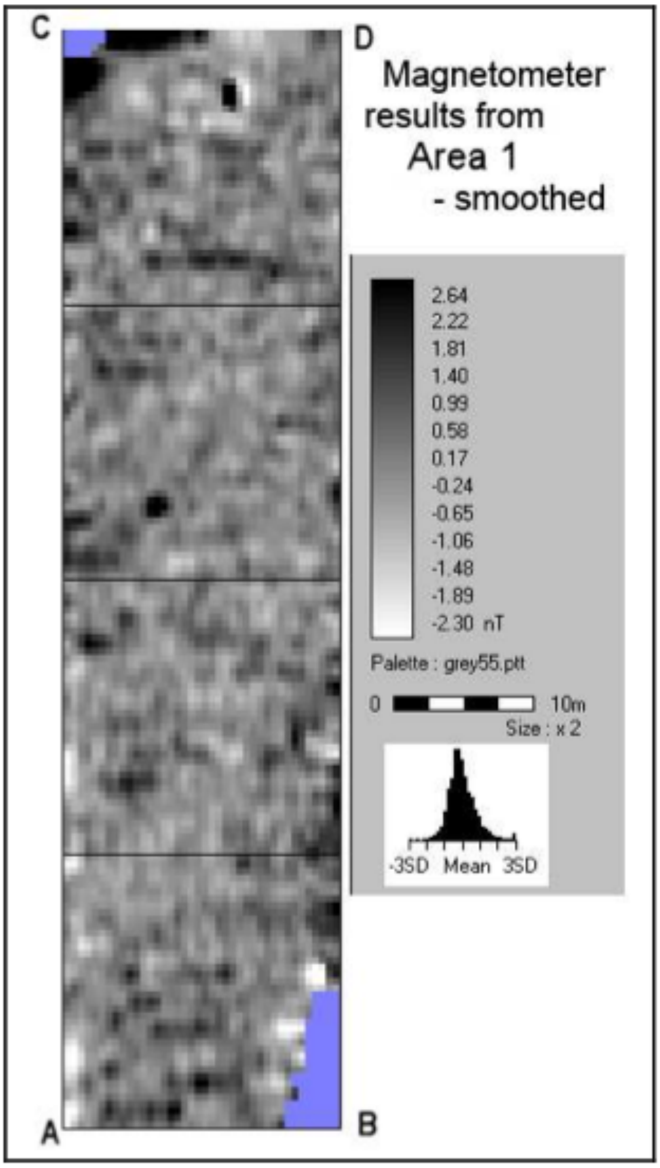

Figure 6.2 Area One magnetometer results (smoothed)

Area Two

Area two is located on the sloping ground to the northeast of the suspected prehistoric mining feature known as 'The Lumb' (figure 6.1). A total of six 20 by 20-metre squares were surveyed resulting in a total grid area of 60 metres by 40 metres. This area included part of the area previously surveyed by an English Heritage team in 1998 (Bray and Horsley 1998). The magnetometer survey of area two revealed a significant dipole feature (Feature A) in the centre of the area (figure 6.3). This feature correlates with the location of a similarly significant anomaly identified during the 1998 survey. This anomaly had the potential for further investigation.

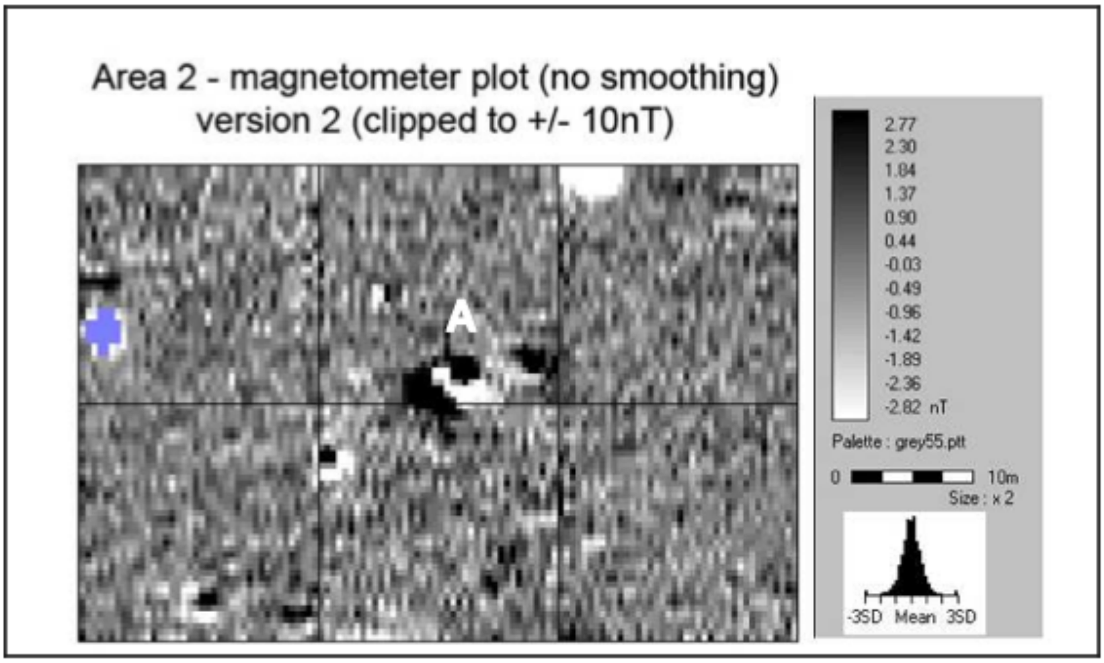

Figure 6. 3 Area Two magnetometer results (no Smoothing, clipped to +/- 10nT)

Area 3

The third area is adjacent to area two and is located on the sloping ground to the southwest of the area known as 'The Lumb' (figure 6.1). A total of eight 20 by 20-metre squares were surveyed giving a total grid area of 80 metres by 40 metres. No previous geophysical survey had been conducted in this area. Results from this survey are shown in figure 6.4 The area is notable for being devoid of any extensive archaeological features although there are anomalies that are worthy of further consideration. In particular there is a significant dipole anomaly, similar to the one noted in area two, in the top left hand grid (feature B). This anomaly is smaller than that identified in area two; however, it is well defined and broadly fits the criteria for a pyrotechnic metallurgical feature.

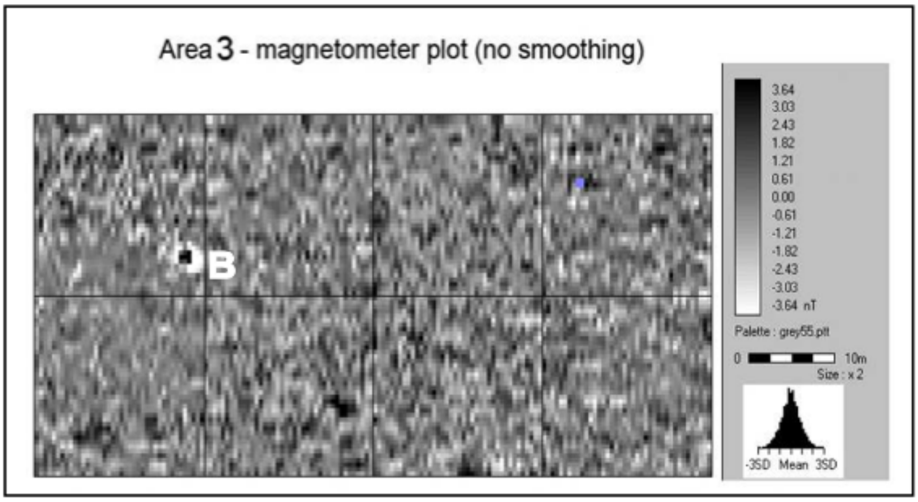

Figure 6. 4 Area Three magnetometer results (no smoothing)

Area 4

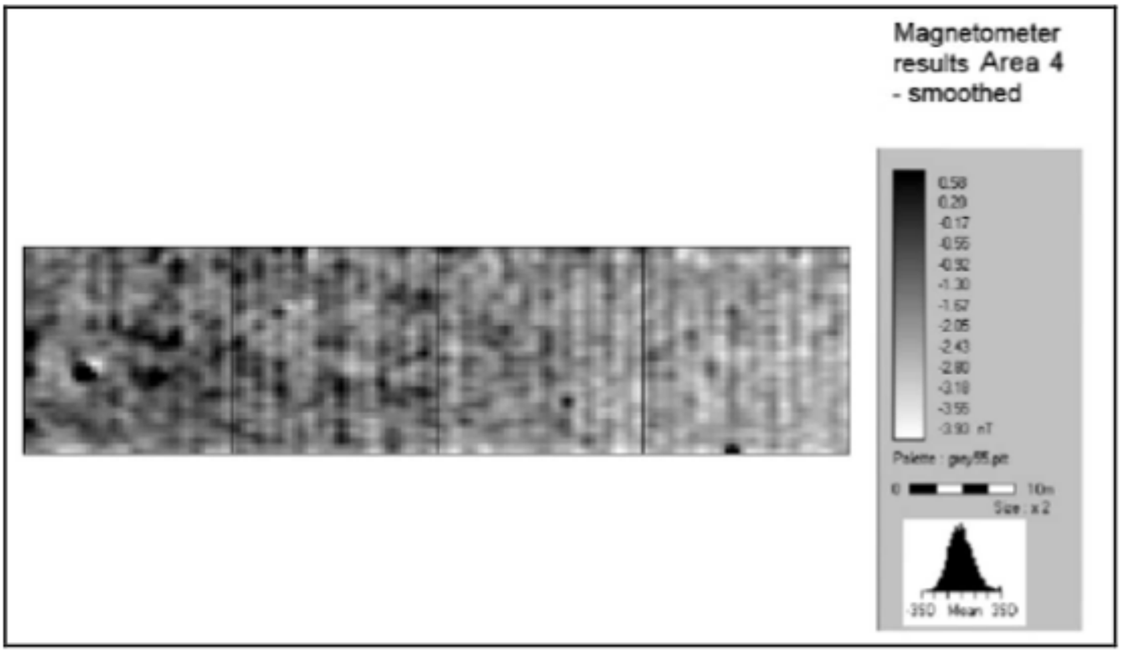

Figure 6. 5 Area Four magnetometer results (smoothed)

The grid in area four extends southeast from the brow of Ecton Hill over level ground away from the trig point (figure 6.1). A total of four 20 by 20-metre squares were surveyed amounting to a total grid area of 80 metres by 20 metres. This survey is again notable for the lack of significant archaeological features; although there is a small dipole anomaly noted on the most westerly grid (figure 6.5). This anomaly is not of the same magnitude of those noted earlier in areas two and three and it is located close to the path, which extends across the ridge of Ecton Hill. It is probable that this anomaly represents a buried ferrous object.

Area 5

Area five extends approximately north south immediately below fly mine on the northwest slope of Ecton Hill (figure 6.1). A total of five 20 by 20-metre squares were surveyed providing a total grid area of 100 metres by 20 metres. The results of the magnetometer survey of area five are shown in figure 6.6 below. Two dipole anomalies that can be seen are suggestive of burnt structures. They are both similar in form, but the one on the left, which spans the boundary of the second and third squares, is notably higher than the one in the fourth square.

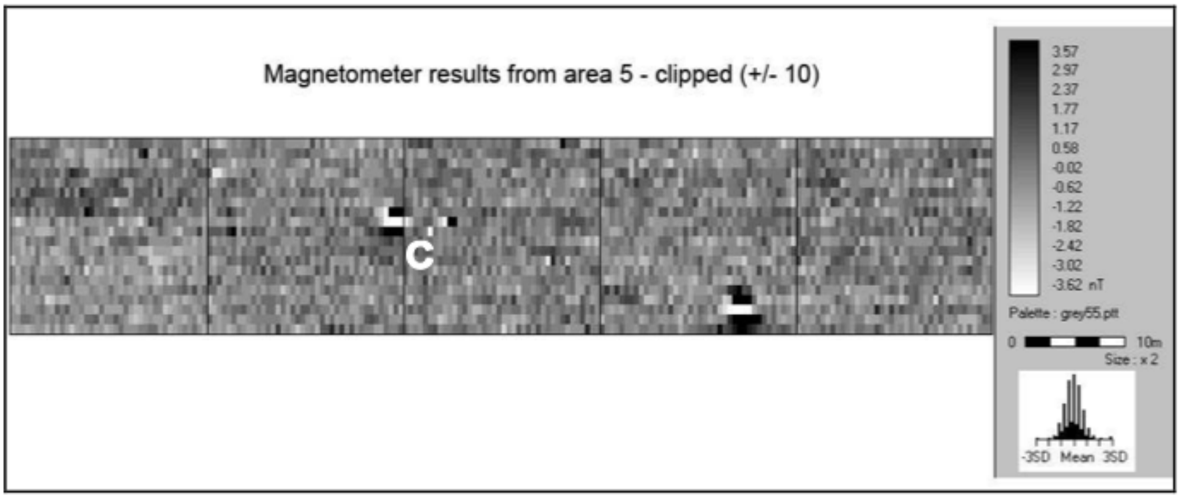

Figure 6. 6 Area Five magnetometer results (clipped to +/- 10nT)

Area six is the furthest removed from the mines, due north of the Ecton Pipe shaft and the remains of the converted engine house (figure 6.1). Area six covers the largest area of level ground in the proximity of the covering 49 20 by 20 metre squares for a total grid area of 160 by 120 metres. In total this survey covered an area of 19,2000 m^2 with four readings per metre resulting in 76,800 data points. Nellie Kirkham (1947) reported finding small pieces of fused ore, similar to material found in the vicinity of the Whiston smelter, in the vicinity of this survey grid, close to the site of the engine house. Similar material was not identified at the surface during the pedestrian survey or during the geophysical or geochemical testing of the area.

The scale of this survey area resulted in additional features becoming visible in the magnetometer results (shown in figure 6.7 below). Two almost parallel linear features are visible running down slope within this survey grid. The southern most of these features curves northwards at its eastern extent to almost join the northern linear feature. These features may or may not be related, but they show up as a weak positive that may be the remains of a field or enclosure boundary (Merrony 2009). A single dipole feature is visible in the gap between the ends of the two linear features at their eastern extent. A further group of four strong dipole features can be seen clustered in the southeaster corner of survey area six. These are no more than 2-3metres in size and are likely the result of ferrous metal just beneath the surface though there is a possibility that they are related to the survival of *in situ* burning (Merrony 2009). Features that appear on the margins of the survey area all correspond with the modern metal fencing in the modern field boundary (Merrony 2009).

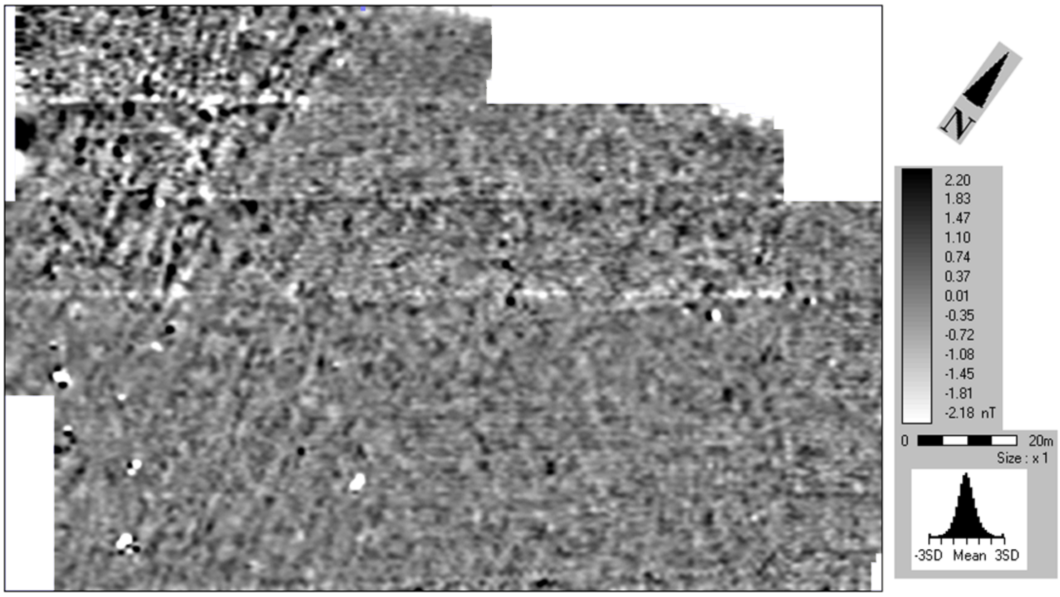

Figure 6. 7 Area Six magnetometer results

6.2.2. Geochemical Results

This section will present the initial results of the geochemical survey. It will include maps, plans and images of the areas tested relative to suspected Bronze Age mining activity as well as more recent mining and disturbances. Geochemical survey was therefore undertaken at a 2-metre resolution for areas one, two, and three and for the most northerly 20 by 20-metre square of area five. A 1-metre sampling resolution would have provided greater detail of the soil composition and distribution of elements; however it would also have exponentially increased the number of samples for analysis and the time required. The goal was to identify potential areas of activity based on higher concentrations of specific elements, including copper, nickel and lead, and a 2-metre resolution provided a level of detail greater than required, but was also manageable within the timeframe. The site, normally used for the pasturage of animals was only available for a few weeks during which time sampling had to be completed. The remainder of area five and the entirety of areas four and six were sampled at 5-metre intervals in order to cover a greater area within a shortened time span. Resolution was sacrificed rather than reduce the coverage. The results of these areas show less specific distribution of elements, but higher concentrations are still visible.

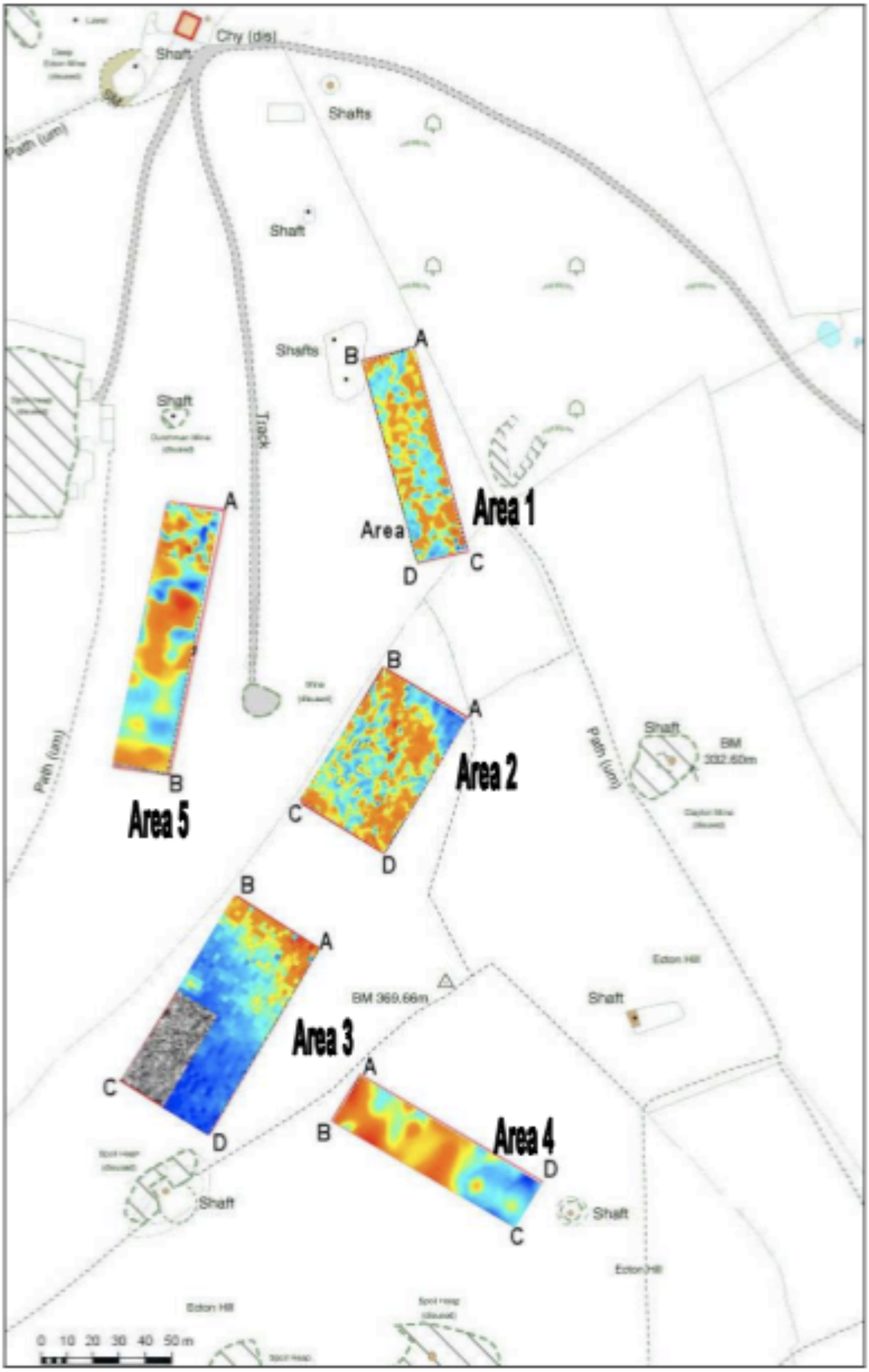

Figure 6. 8 Survey area of stage one showing interpreted geochemical results

Area 1

Geochemical survey was undertaken at 2-metre sample intervals within area one, producing a total of 400 sample analyses. Readings ranged from below detection limits [~30ppm] detected to 6486ppm. Only 2% of readings were above 1000ppm with 75% of readings below 400ppm [parts per million]. The highest concentration of copper can be seen in figure 6.10, along the bottom of the survey grid with the highest values on the bottom left. No clear anomalies or concentrations are evident from the geochemical survey, which can be seen to correlate with the geophysical survey of grid one.

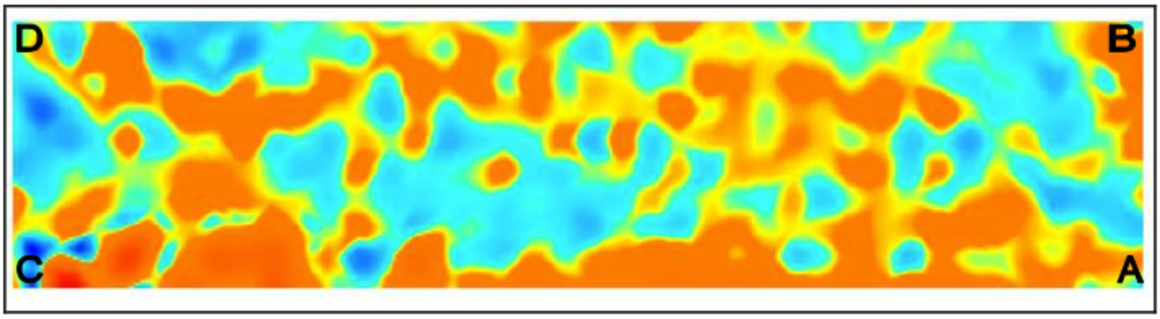

Figure 6. 9 Area One geochemical results (value range <30ppm – 6486ppm)

Area 2

Area two included part of a survey area from two independent surveys conducted in 1998 for English Heritage. Bray and Horsley (1998) conducted a geophysical survey using a magnetometer and Doonan (1998) conducted a geochemical survey. The grid for Area Two was laid out with an anomaly that had been observed in both the geochemical and geophysical surveys of 1998 chosen as the centre point as it had been cut by the previous surveys. Geochemical survey was again undertaken at 2m sample intervals with a total of 600 analyses. Readings ranged from below detection limits to a single high of 18477ppm. Only 1% of readings ranged between 800-1000ppm with 99% of readings between 100-800ppm. The results of this survey and those of the survey undertaken in 1998 show good correlation.

The highest copper concentration constitutes an anomaly visible at the approximate centre point of figure 6.10 (below). This single high value appears in approximately the same location as the geophysical anomaly identified in this area two, survey grid (see figure 6.3). This anomaly was expected based on the 1998 surveys (Bray and Horsley 1998; Doonan 1998) where it was also seen and this latest survey campaign has served to better delimit its extent. There is a notable scatter of higher copper concentrations within the survey grid of area two (figure 6.10). The strong correlation between the geochemical and geophysical survey results, and with previous surveys, makes this anomaly a good candidate for further investigation.

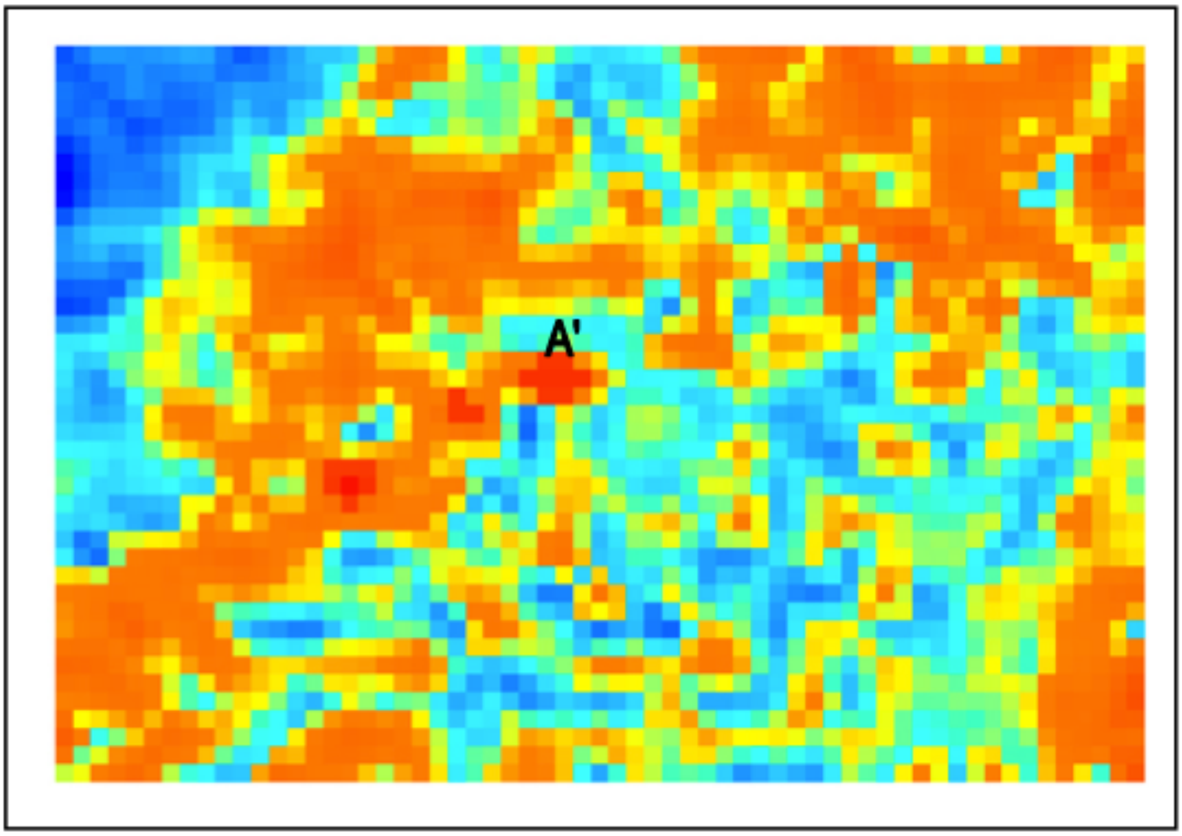

Figure 6. 10 Area Two geochemical results (value range <30ppm - 18477ppm)

Area 3

Only six of the 20 by 20 metre squares that made up this survey grid were subject to geochemical survey, in contrast to the eight for the geophysical survey (see figure 6.8 above). Geochemical survey was undertaken at 2m sample intervals with a total of 600 analyses done in this survey grid. Readings ranged from 6573ppm to below detection limits with approximately only 4% of reading ranging between 1000 – 6000ppm. A more significant 75% of readings were between 100–900ppm. The survey is notable for the relatively low copper determinations made away from the zone associated with mining activity. This is in contrast with area two where copper concentrations remain high even at similar distances from the identified mining zone. The generally high copper concentrations seen on the upper left of figure 6.11 (below) are in the same general vicinity as the magnetic anomaly seen in the magnetometer results for this survey grid (visible in figure 6.4). The confluence of these higher values with the magnetic anomaly suggests the potential for further investigation.

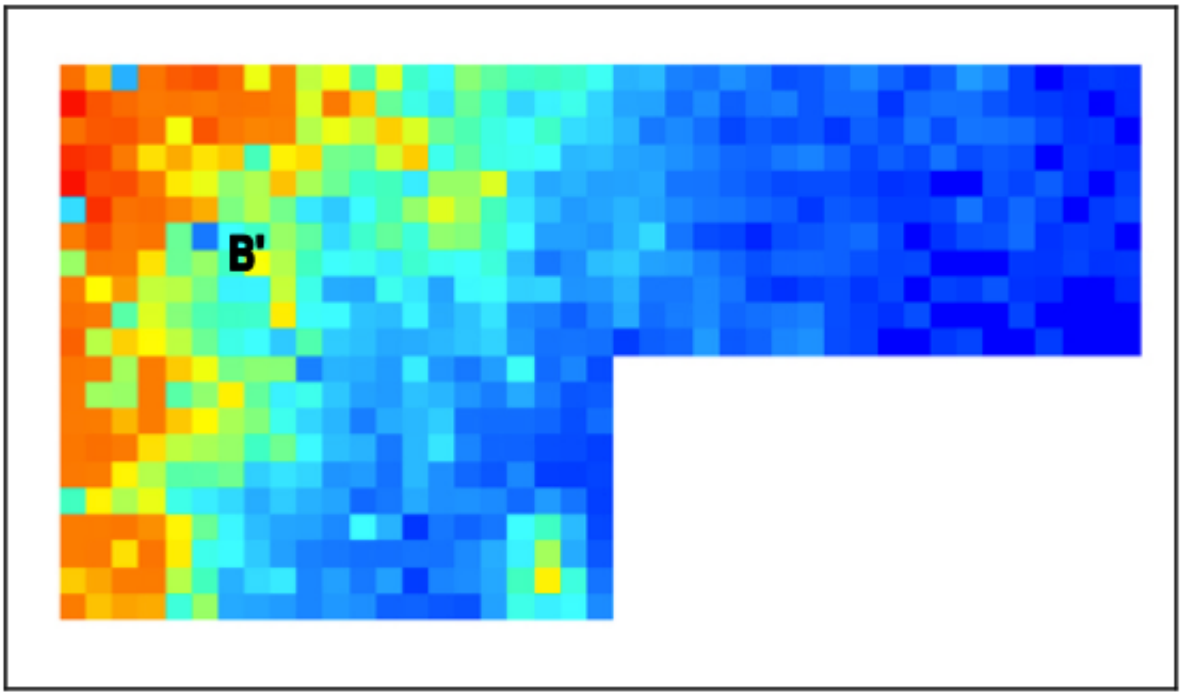

Figure 6. 11 Area Three Geochemical results (value range <30ppm – 6573ppm)

Area 4

Geochemical survey in area four was undertaken at 5m sample intervals because of low copper concentrations detected during random transects prior to systematic survey. A total of 64 analyses were taken from area four. Readings ranged from a very low 157ppm to below detection limits. Approximately 50% of readings were below 100ppm making area four notable for its extremely low copper determinations across the surveyed grid area. The highest copper concentrations were detected towards the brow of the hill, in closer proximity to the mines on the northwest slope. The very low concentration of copper within this grid area stands in stark contrast to the higher levels detected in areas two and three, situated closer to mining features. Despite weak magnetic anomalies shown in this area by the results of the magnetometer survey (see figure 6.4) the low concentrations of copper suggests that this area has little potential for further investigation.

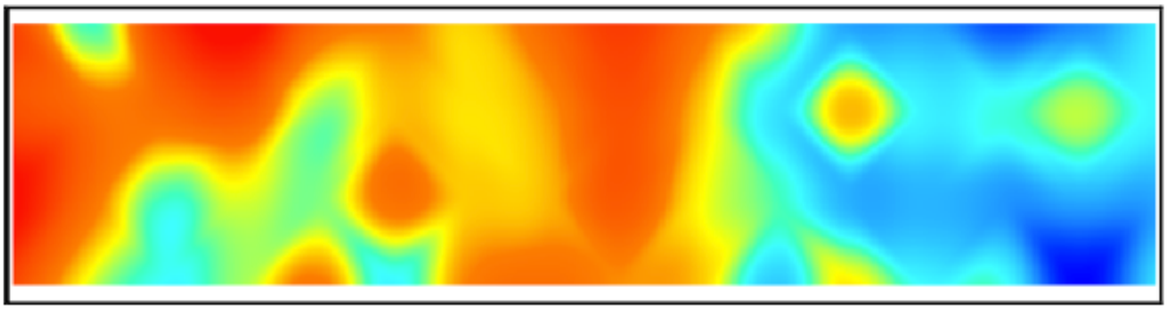

Figure 6. 12 Area Four geochemical results (value range <30ppm – 157ppm)

Area 5

Random transects across this survey grid showed very low copper values across the second to fifth 20 by 20 metre squares prior to systematic survey. Subsequently pXRF readings were taken only at 5-metre intervals within this portion of the survey grid, resulting in 64 analyses. In the northern most square, seen on the far left in figure 6.14, survey readings were taken at 2-metre intervals in 100 analyses in the first grid and 164 total for area five. Readings ranged from 746ppm to below detection limits with approximately 50% of reading below 30ppm. The survey reveals no particular structure but does contain a slightly weaker copper anomaly (feature C) that does correlate with a dipole anomaly identified in the magnetometer results (see figure 6.7). The correlation between that dipole anomaly and the higher copper concentration suggests the potential for further investigation

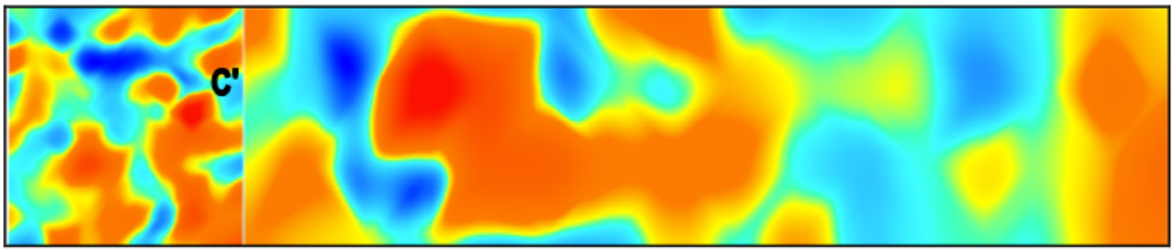

Figure 6. 13 Area Five geochemical results, 5m sampling resolution in grids 2-5 (value range <30ppm – 746ppm).

Area 6

Because of the scale of area six, the geochemical survey was conducted at a lower resolution with readings taken every 5 metres. A total of 200 sample analyses were taken from this survey grid. Readings ranged from a single high of 629.15 to negligible copper present with 71% of readings below 100 ppm. The higher concentrations do correlate with the rough location of the dipole anomalies visible in the magnetometer results (see figure 6.8), but are significantly lower than the high concentrations found elsewhere on the hill. Based on the significantly lower copper concentrations and the likely ferrous origin of the dipole anomalies seen in the magnetometer results, the potential for further investigation at this location is low.

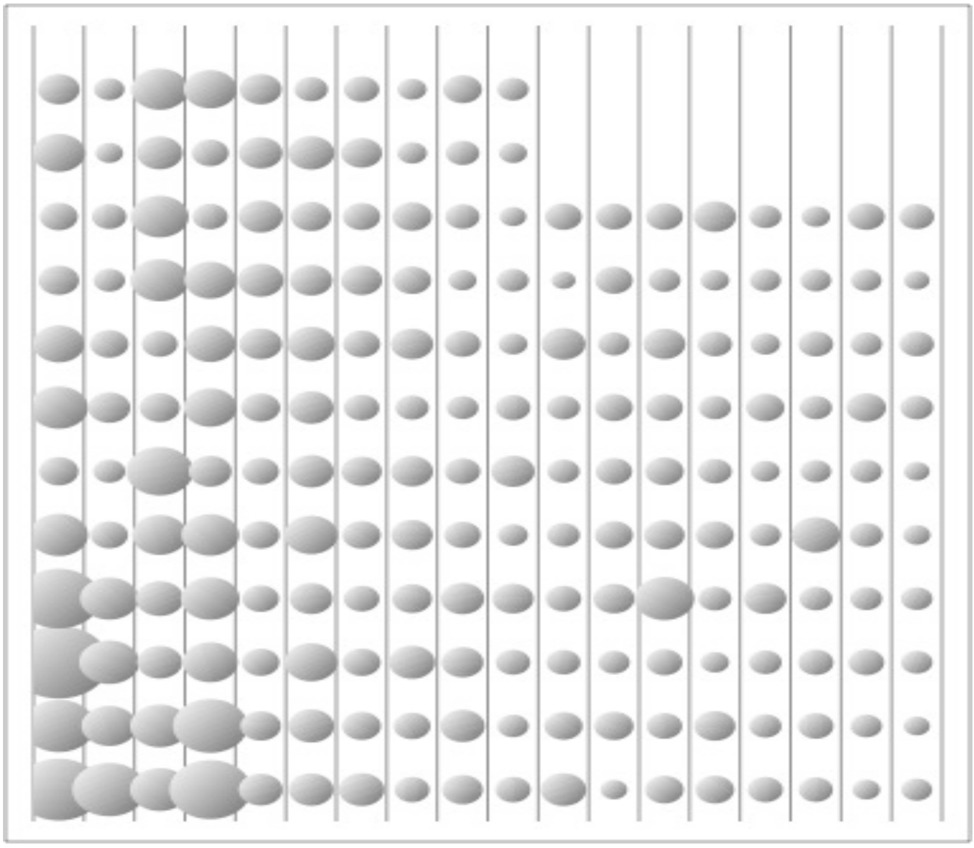

Figure 6. 14 Area Six geochemical results (values range = 36.29ppm - 629.15ppm)

6.3. Test Excavations

Based on the results from the combined geophysical and geochemical surveys, three locations were considered to have high potential for further investigation marked on figure 6.16 (below). Each of these three areas was tested through excavations centred on the features highlighted by the confluence of a magnetic anomaly and higher concentrations of copper. Five by five metre trenches were used. These were not best suited to for the purpose, but were the minimum intervention imposed by English Heritage. The first trench is within survey area two. The feature visible in the centre of this survey area was first identified by geophysical and geochemical survey in 1998 (Bray and Horsley 1998; Doonan 1998). This more recent survey helped to further define the concentration and delineate the extent of the feature in advance of test excavations. The location of the second trench is in survey area three. The high potential of this area was first visible in the magnetometer results and were strengthened by the high concentration of copper seen in the results of the geochemical survey. The final trench was placed in area five, below fly mine. Two dipoles were visible in the magnetometer results of this survey area. The geochemical survey was conducted at a wider resolution, at 5-metre intervals over the dipoles, but a higher copper concentration was still apparent over one of the magnetic features.

Prior to excavation, boundaries were erected around the proposed locations of the trenches using appropriate livestock fencing. The removed turf was methodically stacked so it could be replaced following the excavation, recording and backfilling of the trenches in accordance with the method prescribed by Natural England.

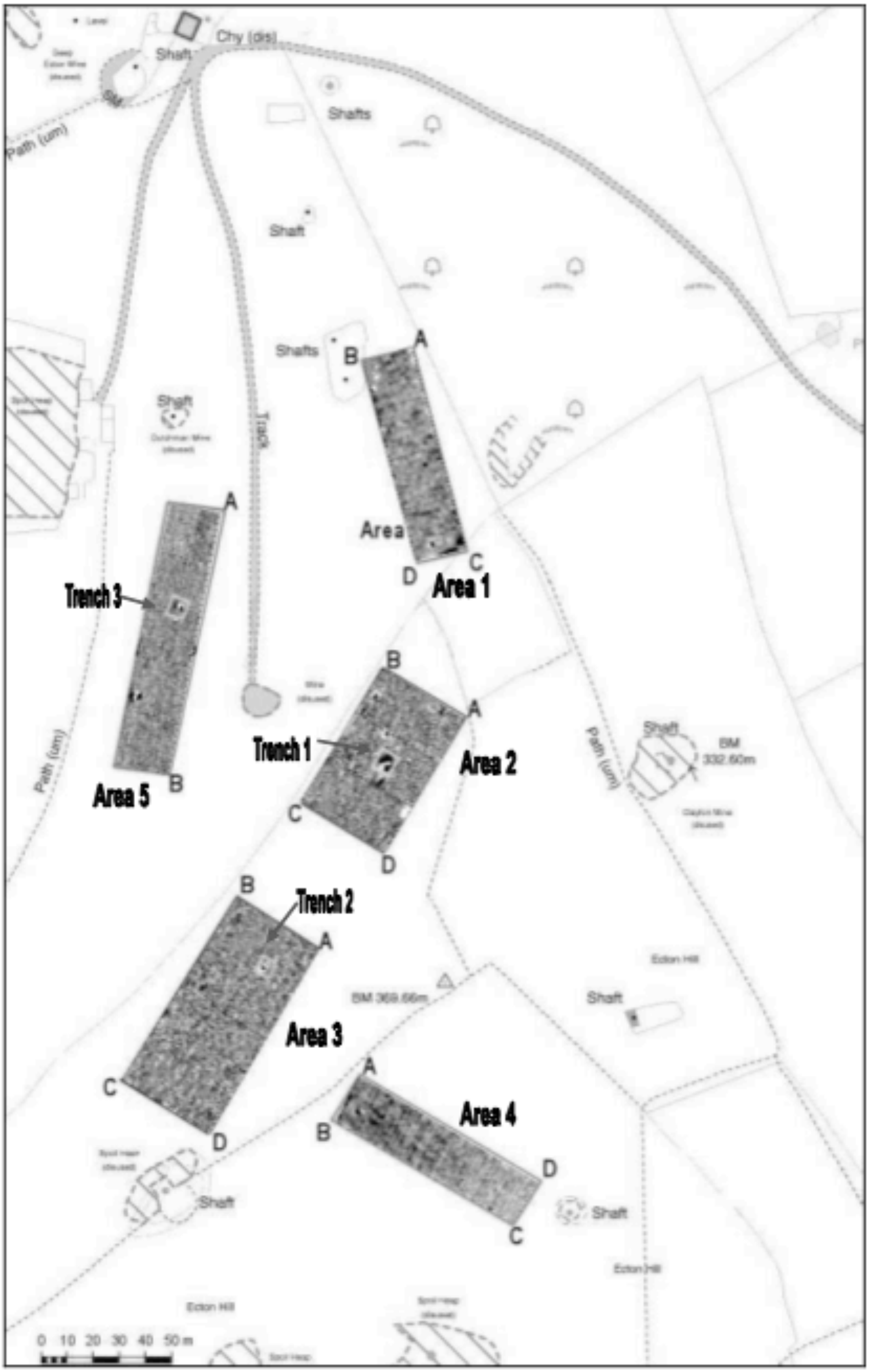

Figure 6. 15 Showing the location of excavated test trenches in areas 2, 3 and 5.

Trench 1

Trench one was located in survey area two on Feature 1 which had also been previously identified in both geochemical and geophysical surveys that had taken place on the site in 1998 (Bray and Horsley 1998; Doonan 1998). A 5 by 5-metre trench was excavated centred on the significant magnetic anomaly shown in figure 6.3 and identified as copper concentration in the geochemical survey (figure 6.9). This anomaly is associated with copper levels in excess of 18,000ppm and is the highest found in the course of the geochemical survey on Ecton Hill. A track way ran across trench one north – south along the flank of the hill to a later limekiln atop the Hill.

Trench one was deturfed by hand with spades. Once deturfed a single soil horizon with a spread of gravel in the vicinity of the track way was revealed. Subsequent cleaning by trowel exposed a light brown soil that extended over the entire trench. Continued troweling through the centre of the trench exposed a significant ferrous object, which on further excavation was identified as an angular modern ferrous object a (figure 6.16).

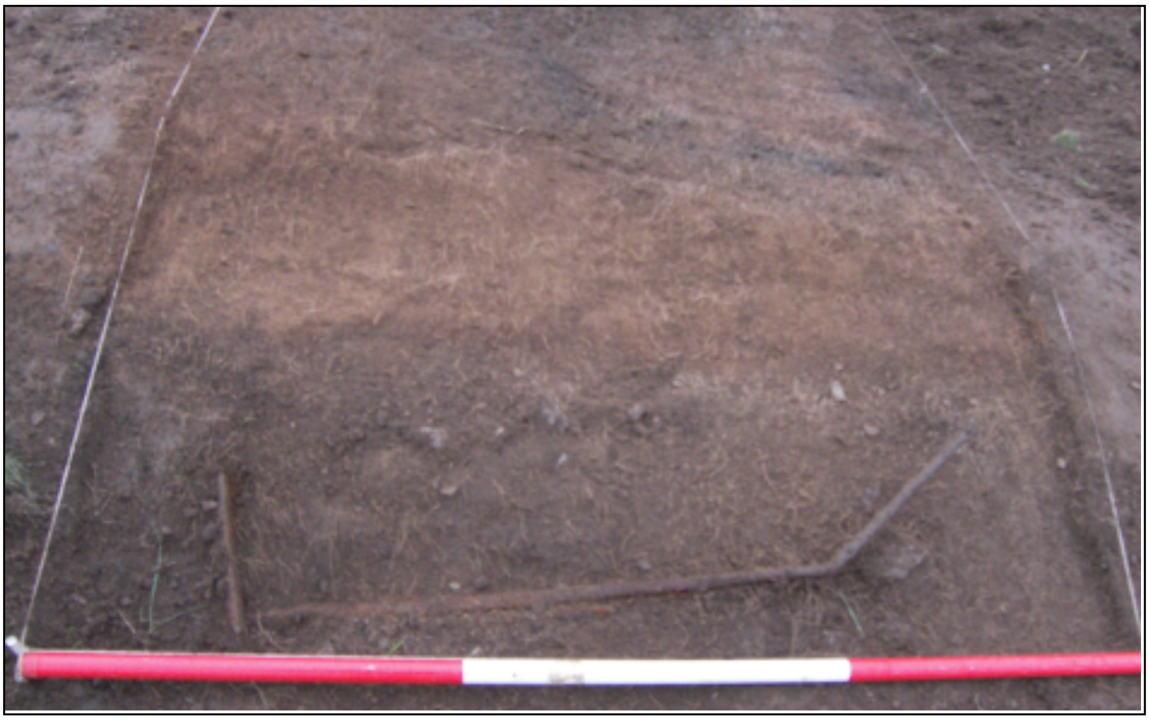

Figure 6. 16 Trench One following excavation.

This object was identified as the source of the dipole anomaly identified in the magnetometer results. Subsequent *in situ* geochemical analysis noted a continued higher concentration of copper in the soil in the vicinity of the ferrous object. Excavation was continued until the limestone bedrock was exposed. No other finds were made. The trench was backfilled and the turf was repositioned in accordance to the method prescribed by Natural England.

Trench 2

Trench two was located in survey area three. It was again a 5x5m trench centred on the significant magnetic anomaly shown in figure 6.3 and in the vicinity of the high copper concentration seen in the geochemical results, visible in figure 6.11. This anomaly was associated with copper levels in the region of 4000ppm in the geochemical survey. There were no visible earthworks or other landscape modification in trench two.

The removal of the turf and subsequent trowel cleaning of trench two uncovered a scatter of limestone block tumble sitting atop a brown red soil. A single feature was noted in the centre of the trench that corresponded with the position of the feature identified in survey. The feature comprised a poorly developed platform that resembled a sheep scar. It was approximately 3m long and 60cm at its widest point. A number of small rock fragments were noted in the soil matrix during cleaning, including a number of mineralized fragments. Neither the fragments nor the feature exhibited any characteristics that suggested anything other than natural

Figure 6. 17 Trench two following the removal of the turf and trowel cleaning.

Sectioning the feature failed to identify any distinct horizon between the path like feature and the red-brown soil that characterized the rest of the trench. The differential drying of the feature was related to topographic variation rather than context

Figure 6. 18 Trench two showing sectioned trench and natural limestone scatter.

Subsequent *in situ* geochemical analysis noted elevated copper levels consistent with those observed in the survey and in particular in the vicinity of the mineralized rock fragments. No finds were made during excavation that could easily explain the dipole anomaly in the magnetometer survey. A single quartzite cobble was recovered near to surface on the northeast side of the trench. It did not appear utilized, but was given to the Early Mines Research Group, who were responsible for excavation of the mines, for further characterization. No other finds were made during the excavation of this trench. Excavation continued until the limestone of the hill was exposed. The exposed limestone protrusion (seen in figure 6.18) proved to be bedrock. Following excavation, the trench was backfilled and the turf was repositioned in accordance to the method prescribed by Natural England.

Trench 3

Trench Three was located in survey area five below fly mine. It was proposed as a third 5x5m trench centred on the more northerly magnetic anomaly, seen in figure 6.6, which correlated with the highest concentration of copper within survey grid five (seen in figure 6.13). The anomaly is associated with copper levels in the region of 700ppm, which is a much lower level than the previous anomalies, but was targeted for further investigation because of the significant connection with the magnetic dipole. Following the negative results from the excavations of trenches one and two a 1 metre by 1 metre trench was excavated directly on the identified anomaly. A modern ferrous object was recovered immediately below the surface that explained the magnetic dipole. The trench was continued to sterile soils with no further recovery of material. Following excavation the trench was backfilled and the turf replaces in accordance with English Heritage.

No significant archaeological finds were made during excavations undertaken in this stage of survey. The modern ferrous objects were removed from the trenches, but not collected or catalogued. The quartzite cobble showed no evidence of wear or modification, but was submitted to the Early Mines Research Group for illustration and further study.

6.4. Stage Two: Pedestrian Survey of Ecton Hill

This second stage of the nested landscape was a pedestrian based visual survey of Ecton Hill. The aim of this stage of survey was to identify known and possible sites on the hill itself along with any potential resources relevant to the reconstruction of the metallurgical *chaîne opératoire*, explored in chapters three and four. However, survey at this stage also attempted to examine the conditions of movement and action within the environment of Ecton Hill. This survey drew on underlying principles that are used within a phenomenological approach, but cannot be considered a phenomenology of landscape.

6.4.1. Ecton Hill: The Survey

In addition to the copper mines, known Bronze Age sites on Ecton Hill include a number of barrows (Barnatt 1996a; Bateman 1861) and natural caves with evidence of occupation, such as sycamore cave (Houdmont 1989; 1991) while the post-medieval mining remains dominate later features. One of the aims behind this stage of the survey was to be able to understand the modification of the landscape that has resulted in its current organization and heavily influences how the visitor experiences the space. This visual survey also aimed to identify other previously unknown or unidentified mining features located on the hill. Potential resources included additional outcrops of copper mineralization; significant accumulations of clay, or sand deposits that may have been exploited by early metallurgists. Metallurgical sites would be identified by any accumulations of slag-like material or crushed ore not related to the later post-medieval ore processing on the valley floor.

The four previously identified barrows are located along the western side of Ecton while Sycamore Cave is located on the eastern side of the hill further south. Three of the four Bronze Age barrows are spread evenly across on the ridge immediately above the northwest face of Ecton, which hosts the copper mines. This ridge is the highest point on Ecton hill. The fourth barrow is located further south on the hill and slightly back from the western slope. It is located on the second highest point on the Hill and highest south of the northwest ridge. The more recent mining remains were no less visible and, while there is a primary concentration of mine entrances on the northwest face, a number of capped shafts remain visible on the top of Ecton. A large open cutting visible along the northwest ridge is a likely limekiln.

Pedestrian survey of Ecton Hill was undertaken on 25-metre transects. These took the location of recent mining activity in to consideration and an effort was made to avoid obvious disturbances associated with the post medieval copper and lead industry. Transects were oriented primarily north south roughly parallel with the eastern and western ridges of the hill and were taken across the top of Ecton, descending the southern slope and along the eastern slope, or back of Ecton.

Figure 6. 19 Map of Ecton Hill showing survey area and additional identified features (1 & 2)

A significant accumulation of clay was identified on a southern slope of Ecton Hill (shown on figure 6.20). This was intersected by a number of animal burrows that had exposed the clay at surface level. As with other clays this material would have required suitable temper in order to withstand the high temperatures involved in metallurgical processes. No additional working areas were visible at the surface during the pedestrian survey of Ecton Hill and no accumulation of slag like material or crushed mineral were identified during the survey. No material was collected in the course of this survey.

Two additional features were identified on the southern end of Ecton, labelled 1 & 2 on the map above (figure 6.20). These may relate to unrecorded mineral exploitation although possible alternative explanations will also be explored. The first (feature 1) is a shallow cutting into the hill with well-defined edges. This is potentially an exploratory opencast working, although it could also be the remains of a small limestone quarry. The second feature (feature 2) is a small opening at the base of a limestone face (see Figure 6.21 below). This feature has been partially in filled with sediment, obscuring the entrance. It could be a natural recess, or cave, in the rock face; however, the opening features a well-rounded profile consistent with fire setting techniques. No other evidence of mineral exploitation was found in the immediate vicinity, nor was copper mineralization apparent possibly supporting a natural origin for this feature.

Figure 6. 20 Feature 2 is likely a natural feature on the southern face of Ecton Hill

6.4.2. Ecton Hill: A Sense of Place

Ecton Hill is a dominant feature within the southwest Peak District. The approach to Ecton along with access to and ascent of the hill has been heavily influenced by the developments of the mining industry since the 17th century. The roads and pathways, remnants of the industrial past of this area, direct the movement of the visitor into and through the Manifold valley, which plots its course along the western side of Ecton. The modern path follows the route of the former Leek and Manifold light rail that ran through the valley in the early years of the 20th century. Approaching Ecton Hill from the north, the first feature the visitor encounters is Apes Tor where the folded limestone and shale geology of Ecton is displayed in an impressive rock face. Following the modern routes takes the visitor around the west side of the hill into the Manifold Valley. Here the northwest face rises dramatically from the eastern bank of the River Manifold, in an impressive natural amphitheatre, to a ridge crowned with a line of three barrows. It is on this steep slope, overlooked by the barrows above, that the remains of Bronze Age mining activity have been located. It is also in this general vicinity that the post-medieval mining was concentrated with the focus for much of the development in the valley below and lower slopes of the hill.

Standing in the Manifold Valley among the ruins of the ore processing and smelting structures of the post-medieval working platform, the hill rises sharply to obstruct visibility and dominates the sense of place. From this vantage point Ecton Hill looms over its surroundings, sheltering and enclosing the valley. The natural amphitheatre like shape of the slope aids this impression. Ascending this slope follows a blueprint informed by the more recent development of the site. A driveway directs movement past houses that are the remnants of a hamlet that once existed at Ecton. From there a path leads up the precipitous to the converted engine house. The path then continues past the remains of open mine shafts, including Stone Quarry mine, further up the slope to the ridge above the Lumb where the three barrows guard access to the plateau beyond. A trig point has been placed atop the most prominent barrow. The barrows mark the highest point of the hill and from them the land slopes away gently to the southeast. Beyond the northwest ridge, the top of Ecton can be characterized as a plateau crossed by a number of pathways and upon which a number of cattle and sheep are often found grazing.

Figure 6. 21 The northwest slope of Ecton Hill

If one ignores the modern trapping that direct the visitor to, around, and up the hill or valley, a number of potential routes can be traversed to reach the mines on the steep northwest slope, just behind Apes Tor. The most direct route is to ascend the western face. This is the most obvious path and the one to which visitors are directed by the modern structure of the Manifold Valley. The length of the western face of Ecton is a steep escarpment that looms over the Manifold and landscapes beyond. This face forms an edge, or barrier to movement into and out of the valley that must be carefully traversed.

The eastern slopes, on the other hand offer a different experience. The ridge of the hill sits less dramatically above its surroundings and still dominate the skyline, but a longer and gentler slope respects the landscape from which it rises, retaining a sense of connection with the undulating features of the White Peak between the Manifold and Dove valleys. The ascent of this slope is a less arduous journey than the western face offering the pedestrian traveller an open face across which to weave a path to the summit. This slope ends again with a slight ridge above the central plateau. To reach the mines this plateau must be crossed. The mines then sit a short distance down the steep western slope. This path presents an easier ascent. Depending on the approach to the hill, this route could be a better choice. Knowledge of the location of the mines would be needed, as they do not become visible until cresting the western ridge. The only barrier to movement, excepting modern fences and barriers, is the spring that runs through a deep channel at the base of the eastern slope of Ecton Hill. This spring flows roughly north from approximately the mid point of the hill and the Manifold just north of Apes Tor. Although a significant rise, this eastern incline is gentler that the precipitous western edge, and invokes a connection with the lands to the east, rather than presenting a barrier that must be traversed, as does the western face.

Figure 6. 22 The eastern slope of Ecton Hill

The north face of Ecton Hill cannot be easily ascended. Starting with the feature known as Apes Tor, the northern slope of Ecton is a series of sheer cliffs and incredibly steep slopes. These proved to be impassable and are covered in thick vegetation. The southern slope of Ecton proved to be the easiest to traverse, gaining the central plateau with the least physical exertion. A steep vale, a common formation in the limestone of the White Peak extends from the Manifold Valley to the central plateau on the top of Ecton Hill. It has a sense of being disconnected from its surroundings, much like the deep dales and river valleys elsewhere on the White Peak, which is further is reinforced by the woodland vegetation that grows within the vale. Taking this route to ascend Ecton Hill transports the visitor from a visually restricted, albeit relatively open, space on the banks of the Manifold River through a tightly enclosed passage onto a very open space atop Ecton. Upon emerging from the vale onto the top of Ecton a Bronze Age barrow is immediately visible. As the mines are not at all visible at this point the barrow serves as something of a landmark, directing the attention of the visitor towards the northwest and the line of three barrows that dominate the ridge above the mines. A ridge on either side of this dale extends the central plateau southward, into the meandering Manifold Valley, before dropping steeply away. Each of these possible ascents of Ecton Hill, present different potential pathways to the copper mines.

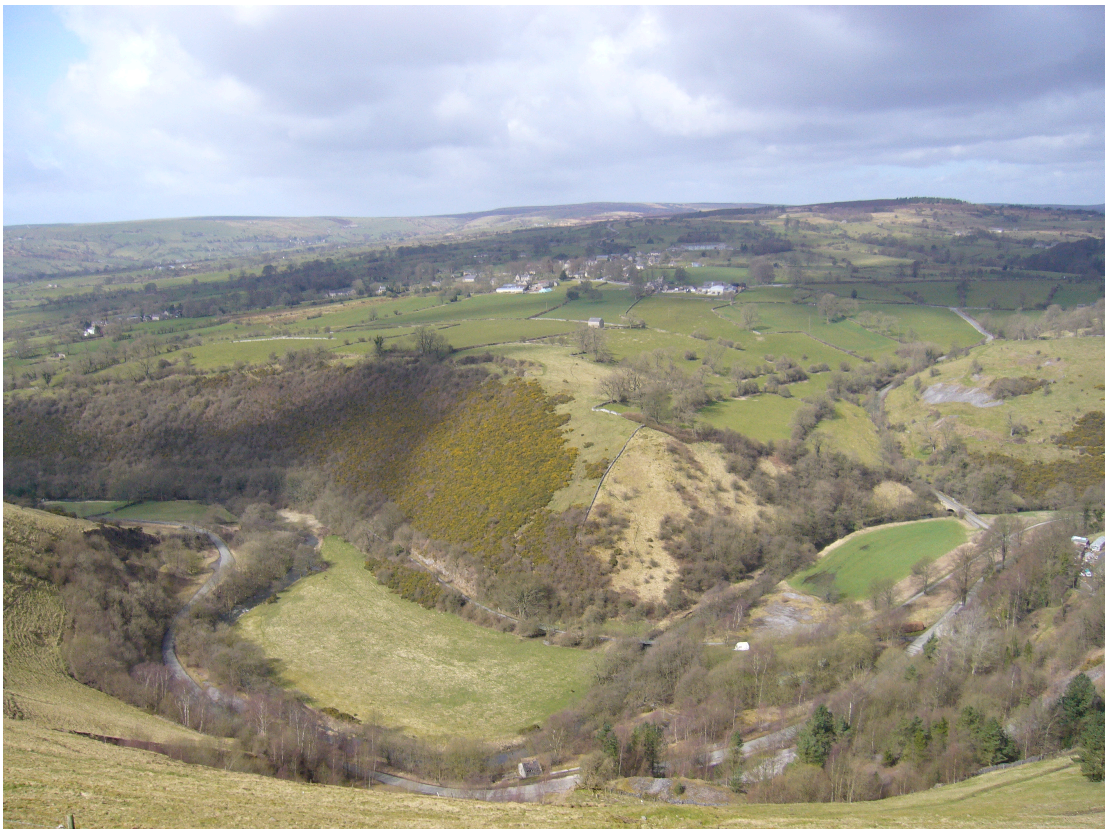

Figure 6. 23 View to the west from top of Ecton

From the top Ecton Hill is a near limitless view to the north and west. To the east the undulating landscape is broken only by the River dove, which flows from the north and disappears into the depths of Beresford and Wolfscote dales. To the southeast the slopes of Narrowdale and Wetton hills restrict the view, while Wetton Hill and Mere Hill form visual barriers to the south. The prevailing winds also have a dramatic effect on the sense and experience of space as the visitor moves up and across Ecton Hill. The Manifold Valley below the western edge of Ecton is sheltered, but as one ascends the slope the wind asserts its presence. With nothing to block it, the wind blows relentlessly against the western edge of Ecton. The shape of northwest slope captures the wind and funnels it up the slope where it buffets the visitor and creates a cacophony that imbues the place with a sense of urgency. Retreating to the east the effects of the wind are reduced as the land slopes away from the western ridge. Ecton itself largely shelters the south and eastern slopes, but as one moves onto the central plateau it becomes a noticeable feature of the space.

6.5. Stage Three: Engaging with the Wider Landscape

This third and final stage of the nested landscape survey encompasses the largest area, extending to a radius of 5 kilometres from the copper mines on Ecton Hill in an effort to include a range of environments and archaeological remains. Accordingly, it was undertaken in three parts. The first past was a desk-based assessment of the landscape and resources in the hinterland of Ecton Hill. This was used to inform the second part, which was yet another stage of field survey. As outlined in the previous chapter the scale of this survey area necessitated a targeted approach. Watercourses were the primary target based on an observed association between copper production and water sources at other sites in Europe as well as a potential or perceived juxtaposition of ore processing and a water source at excavated mining sites in Britain and Ireland (O'Brien 1994; Ottaway and Wager 2000; Timberlake 2003b; Wager 1997). The final part to this stage of survey was a GIS based analysis of the content and distribution of Bronze Age archaeology in the landscape surrounding Ecton. This also included a view-shed analysis, which was intended to understand the importance of the mines within the wider landscape and socially created space.

6.5.1. Desk-Based Survey

The desk-based survey extended even further into the southern peak district than the 5km radius used in the remainder of this stage. The justification behind this extended range is to try to identify additional geological deposits, primarily copper mineralization and potential sources for the non-local quartzite cobbles used as hammer stones in the Bronze Age copper mining at Ecton. This research was drawn from maps and other published sources. Ecton is not the only source of copper ore in northern Staffordshire and a number of other mines were operated along the Manifold and in its vicinity during the post-medieval period. It should be noted that no evidence has yet been identified for the exploitation of any other source in the Bronze Age and some of the copper deposits that were exploited in more recent history may not have been known or available to the Bronze Age inhabitants of this region.

The Ecton Mines were sources of both lead and copper ore as well as sphalerite, a zinc ore. In excess of a dozen different mines were actually operated on Ecton Hill, split between the Duke of Devonshire's liberty and the neighbouring Burgoyne liberty, over the history of its operation (Porter 2004; Porter and Robey 2000; Robey 1975; Robey and Porter 1972). Across the River Manifold lay the lesser-known Dale mine along with a number of smaller, primarily lead, mines (Robey 1972; 1973; 1974). Although records of the operation these mines are scarce, the Dale mine was worked for lead at about the same time operations at Ecton were peaking and output began to decline (Porter and Robey 2000). While the Dale and other mines on the west side of the River Manifold were worked for lead ore, copper ore was present and bornite, a copper sulphide, was identified in the disturbed spoil of Dale Mine during field survey.

Even further west, the mines of Upper Elkstone are connected to the Manifold River by Warslow Brook and the River Hamps, which both flow into the Manifold. Copper was first reported in the Upper Elkstone region By Robert Plot in the late 17th century, prior to any known mining (Plot 1686). Three copper mines, Hill House mine, Royledge mine and the New York mine were operated in this region through the 18th and 19th centuries, broadly contemporary with the operations at Ecton (Porter and Robey 2000). A barrow located among "ancient Royledge stope workings" (Porter and Robey 2000: 135) may allude to a much earlier knowledge of the copper available in this area; however no archaeological evidence for Bronze Age exploitation has yet been identified. Very little remains in this region of the mines; although tips are still visible, shafts appear to have been back filled or collapsed.

Just to the south, along the west bank of the River Hamps and roughly five and a half kilometres west of Ecton, are the Mixon Mines. These are another grouping of copper mines that exploited deep deposits during the height of the British copper mining industry (Porter and Robey 2000). Again, both copper and lead were found mixed in this mineral deposit. A number of scattered waste mounds and shafts attest to the mining history of this site; however the main site has been quite thoroughly cleaned up and Mixon farm is now located on the site.

An unnamed mine is visible from the Manifold Trail on the west side of the river across from Swainsley, where the Ecton stamps yard once stood. Botstone mine is found across the manifold from the Wetton Mill, off the south end of Ecton Hill. The mining spoil is still visible just north of the car park on the west side of the Manifold River.

Legal documents reveal that lead was raised from an unknown mine in the parish of Grindon in the 14th century (Porter and Robey 2000). A number of small trials are located within this parish, about which little is known. The majority appear to have been lead mines along the west side of Ossoms Hill, south of Hoo Brook in the vicinity of Botstone mine, described above. Ford Mine is another small mine in Grindon Parish that was worked for copper (Porter and Kirkham 1998a; Porter and Robey 2000). Fragments of copper ore are visible in the mining spoil associated with this trial. The trial exploited a vein marked on Geological survey map 111 that extends to Grindon Moor where no mining is known, but Porter and Robey (2000) have observed ‘disturbed ground’. This area is also associated with one of the rare barrows on the Dark Peak.

South of Beeston Tor, the Bincliff, Oversetts and Highfield mines are a grouping of lead mines. These are primarily shallow lead rakes similar to those known in Derbyshire (Porter and Robey 1974; 2000). It is close to this dense grouping of mines that an additional hammer stone, or possibly crushing stone was located (Howarth 1899). It is unclear whether it was recovered from Carrington’s excavation of Long Low or from the more immediate vicinity of the copper mine although Picken (1999) suggests the date of its recovery may be more closely connected to the re-working of the mines. Further to the east small deposits of copper were worked in the vicinity of Reynard’s Cave in the 19th century. These reportedly occurred in the Dove Dale along the River Dove, although these could not be identified in the field.

Beyond the defined survey area copper mines in the vicinity of the hamlet of Waterfall took advantage of copper minerals on the slopes of the hill below Waterfall Low (Porter and Robey 2000). Again, no evidence for Bronze Age exploitation has been noted in this area, but little archaeology has been undertaken in this area. Copper and lead deposits are also known in the Weaver Hills Area, south of the Peak District between 12 and 25 km from Ecton (Porter and Robey 2000).

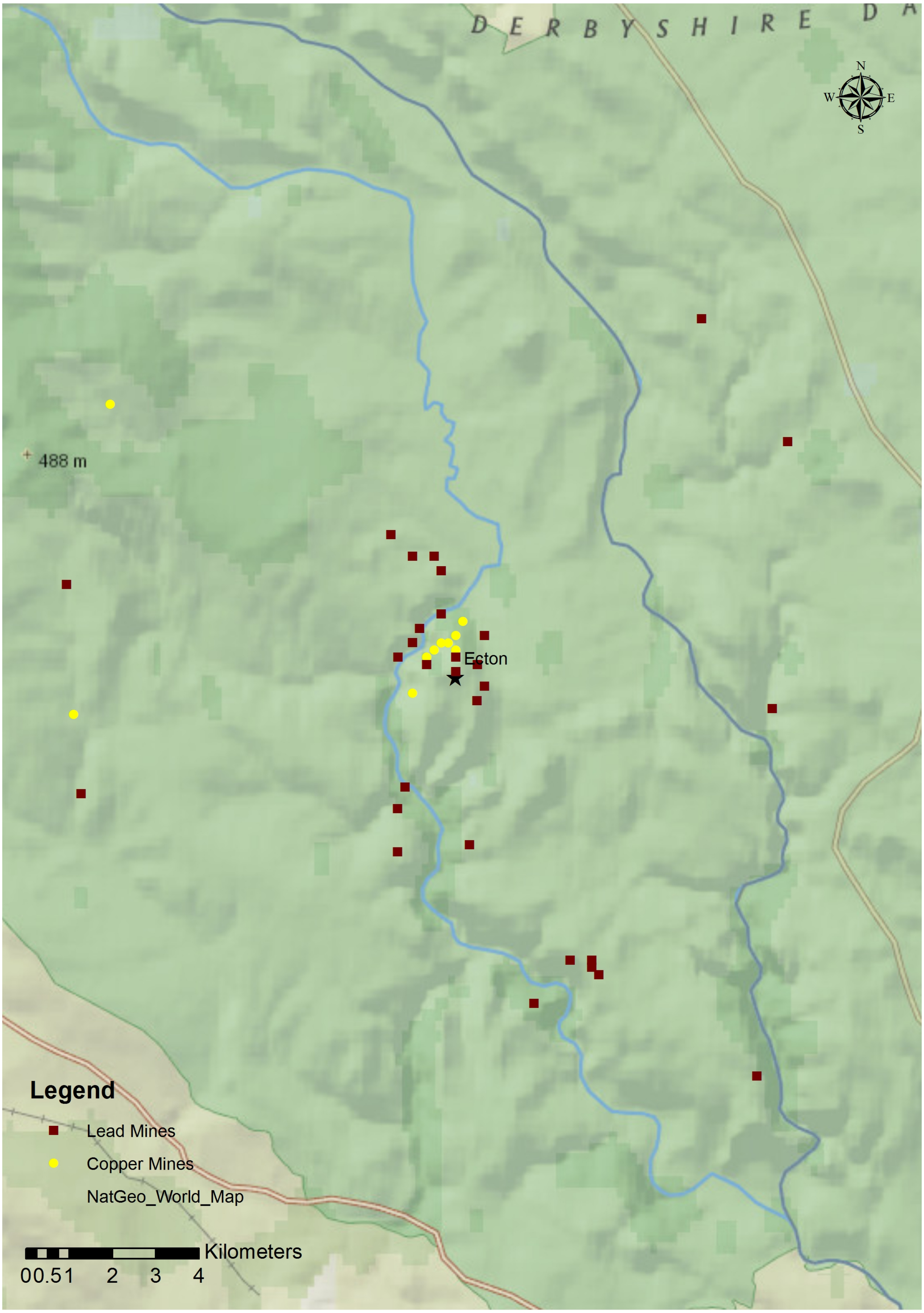

Figure 6. 24 Distribution of copper and lead mines within the survey area

Finally, no deposits hosting quartzite cobbles were identified within the survey area during this desk-based study. The entirety of the survey area is on carboniferous sedimentary formations with no other significant geological deposits. The likely source of the quartzite cobbles that were used as hammer stones during Bronze Age mining at Ecton are the so-called Bunter beds (Pickin 1999).These fluvial deposits are dominated by sand, but also carry well rounded quartzite and sandstone cobble and mark the course of the ancient Budleighensis river flowing north from Brittany in the Triassic period (Audley-Charles 1970; Gaunt and Girling 1996; Steel and Thompson 1983). The Bunter, or Chester beds (Middleton 1986) are a well known feature of Cannock Chase in southern Staffordshire and the River Trent catchment, but these deposits also occur on the boundaries of the Peak District (Bentham 2006; Steel and Thompson 1983). The closest identified quartzite cobbles are, as asserted in Chapter Four, in the bunter outcrop in the vicinity of Hulme, some 20km from Ecton (Steel and Thompson 1983), but they may have been available throughout the exposed distribution of the bunter beds on the margins of the Peak District (Bentham 2006; Steel and Thompson 1983).

Figure 6. 25 Exposed bunter deposits (after Bentham 2006)

6.5.2. Field Survey

The desk-based research, reported in the previous section, was used to inform the field survey at this stage. While the observations of additional identified copper deposits were included in the above section, this section will present the results of field-survey that was primarily focused along the banks and fluvial deposits of the waterways that rise and cross the roughly 80km^2 survey area. This includes a significant section of the River Manifold and a nearly parallel section of the River Dove. A small section of the River Hamps also features within the southern extent of the survey area, where it joins the river Manifold at Beeston Tor. The survey area also includes a number of streams and springs that flow into either the Dove or the Manifold. Survey was dependant on access to land granted by landowners and areas of public access. This survey stage also employed a phenomenological aspect as used in the second stage of survey, and was used to further inform the GIS based analysis detailed below.

Transects of the fluvial deposits were of varying lengths and depended on the extent of the deposit. This part of the survey was intended to address the potential availability of suitable hammer stone material, and quartzite in particular, within the immediate hinterland of the Ecton mines. The River Dove runs relatively freely though the northern section of the survey area, but upon entering Beresford Dale it becomes heavily channelled. Artificial banks and weirs have altered the nature of the river thorough the Beresford and Wolfscote Dales the southern section of the survey area through. Beresford Dale and, to an even greater degree, Wolfscote Dale are deep, steep sided ravines that seem to remove the course of the river from the limestone landscape above. A roughly 7.5 km length of the River Dove was surveyed from the point where it entered the survey area to the east of the village of Sheen and northwest of Hartington to the village of Milldale in the south.

The artificial channelling of the River Dove severely limited both the fluvial deposits and exposed banks available for survey along the southern extent of the Dove. Several transects were surveyed along the River Dove north of Beresford Dale; however, no quartzite cobbles were found in any context during this leg of survey. The absence of identified quartzite of any size in this river is not surprising given the surrounding geology, which is dominated by gritstone in the northern, dark peak, section and limestone in the southern section that cuts through the White Peak.

Only three springs join the River Dove within the survey area. One, in the northern section, is very small, serving to drain the valley side above and was inaccessible at the time of survey. The remaining two join the river in the brief opening between the Beresford and Wolfscote Dales on the limestone plateau. Both are unnamed; however, the more northern one has been partially channelled along Beresford lane. Survey of this spring recovered a moulded clear glass jar and three ceramic fragments.

The final spring to feed into the Dove rises close to the base of Narrowdale Hill. The banks of this spring were mostly overgrown with vegetation; however, erosion of the valley sides revealed a large amount of mixed sand and sediment close to its western extent. Closer to its confluence with the River Dove exposed banks made survey much easier. Only natural sediments were observed, including quantities of sand. No artefacts were collected along the course of this spring.

There is significantly less artificial channelling along the River Manifold than there was along the course of the River Dove. However, the river was modified in the post-medieval period along Ecton Hill to facilitate mining and smelting operations and to operate the stamps yard built at Swainsley. The modern river is not channelled, but banks have been reinforced at points where the river is crossed by bridges. There are also far fewer weirs on the Manifold with two near Hulme End and a further two near Weag's Bridge at the southern end of the survey area.

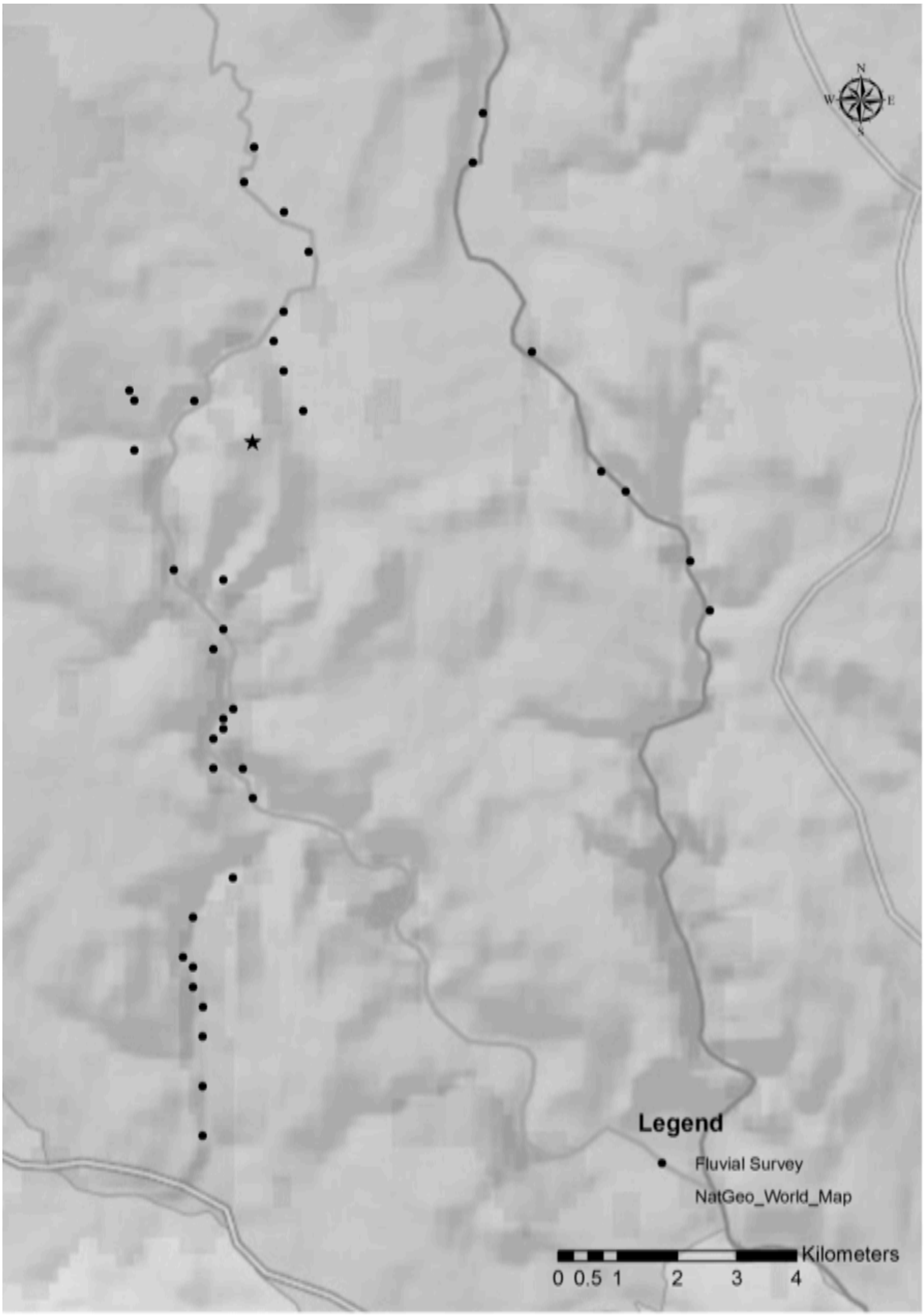

Figure 6. 26 Map of survey area showing location of transects on fluvial deposits

There were far more fluvial deposits along the course of the Manifold because fewer weirs and artificial banks have been built along the river. Again, no quartzite was identified in the course of this survey. Over the summer of 2011 the River Manifold ran dry from approximately Wetton Mill to the southern extent of the current survey area. The opportunity to survey the dry riverbed resulted in two transects walked along the riverbed from Wetton mill to Beeston Tor at the southern end of the survey area. A single quartzite cobble was identified during the survey of the Manifold (see image 6.x below). No other quartzite was identified in the course of this survey. It is likely that the single example noted in this extensive survey represents a discarded cobble that had been brought into the region, rather than fluvial sediment.

Far more water ways join the Manifold than join the Dove within the survey area including: the river Hamps, Hoo Brook, Warslow Brook, Blake Brook and a number of unnamed springs and channels. The majority of these watercourses, 10 of the total 16, join The Manifold from the west where several drain the moors of the Dark Peak. Survey of these watercourses identified two additional quartzite pebbles. These were both found in a small spring running between Warslow and the Manifold; however, these pebbles were flat and well-worn representative of a marine or lacustrine origin, rather than fluvial environment. These pebbles had likely been washed a few feet down stream from a pile of construction sand and gravel that had been placed adjacent to the spring, rather than in the surrounding geology.

Field survey identified a scatter of crushed malachite and mineralized calcite amid green stained soils in the stream bank on immediately below the east slope of Ecton Hill. This site was not excavated, nor has it been dated, but was identified solely based on the green copper staining of sediments and the crushed material eroding out of the bank (see figure 6.24). There is no record of mineral processing in this location during the post-medieval mining period at Ecton and the depth of the deposit alludes to a much older ground surface.

Figure 6. 27 Map showing location of two possible metallurgical sites

Figure 6. 28 Site 1 - crushed vein material and copper staining

A second possible site was located across the Manifold River from the mines, along a small spring flowing east from the village of Wetton into the Manifold south of the mines. The site is a small, low mound that sits beside this watercourse. Slag-like material was found in the back dirt of an animal burrow that disturbed the site. A flint flake was also found on the eroded bank of the spring immediately below the site. While initially promising analysis of the slag like material recovered from this location showed inclusions of coke, indicating the use of coal, rather than charcoal in its creation. This indicated that the material is of a much later date and note related to Bronze Age activity.

6.5.3. GIS analyses

GIS based analyses were used as a means of interrogating the recorded archaeology of the Late Neolithic – Early Bronze Age surrounding the mines at Ecton Hill. This data was used to inform the field survey in an attempt to focus efforts in locating additional Early Bronze Age sites with a specific goal of establishing the possibility of metallurgical sites in association with trace evidence of habitation or other activity specific sites. The Late Neolithic and Early Bronze Age archaeological remains have been described in very similar terms in the Peak District, there are few traces of life and habitation, but the evidence of funerary practice, dominated by characteristic round barrows, is highly visible in the landscape (Barnatt and Collis 1996; Hawke-Smith 1981; Kitchen 2001). The construction of these barrows creates a new sense of 'place' that transcends the act of creation and leaves a durable structure that alters the landscape and redefines the use of surrounding space (Bradley 1993; Tilley 1994). These features were modifications within an inhabited landscape that were employed as mortuary monuments, but may not have been constructed, maintained or understood by just a single kin group. They may have belonged to, or been places that recalled the ancestors (Barrett 1994a; Edmonds 1999), or may have been an articulation of membership within a wider community, albeit with individual groups practicing different rites within broadly similar traditions (Kitchen 2001). The barrows may have been used to legitimate claims of tenure or, perhaps more likely, access to specific spaces or resources within the landscape, through community membership or through decent from a specific group or individual involved in the development of the space or resource (Barnatt 1996c; Barrett 1994b; Edmonds 1999; Tilley 1994).

The treatment of the deceased, the form and location of their burial and the deposition of goods are conscious choices enacted by the living population within an established social framework and an encultured landscape (Barrett and Needham 1988; Bradley 1998; Needham 1989). Therefore the location of mortuary structures and the choices of material within reflect the lives of the Bronze Age people who inhabited the landscape surrounding Ecton hill (Watson 2001). By engaging with this aspect of the archaeological record it is possible to place the copper mines within a contextualized landscape inhabited, not only by the dead who dwell in the barrows, but by the living who constructed and interacted with the spaces and places they represented. This can be seen as an attempt to move the static remains into a more dynamic, inhabited environment where the treatment and location of the deceased within the landscape is of great social significance (Parker Pearson 2003)

Both sets on analysis were conducted using ArcGIS 9.3 and a database of Early Bronze Age sites situated within a ten-kilometre survey area, centred on the copper mines and associated barrows of Ecton Hill.

The first set of analyses involved the plotting of material recovered from the vicinity of Ecton. The majority of this material has been recovered from funerary contexts, with a clear bias towards the Late Neolithic – Early Bronze Age round barrows. There is currently not sufficient radiocarbon dates among the barrows to establish a tighter dating resolution in this area of the Peak District and some of the barrows may predate the copper mines; however there is a greater concentration of barrows within a five kilometre radius of these mines than almost anywhere else in the Peaks (Barnatt 1996a). The construction of a GIS database of sites and recovered material relied on antiquarian accounts, published excavations and the HER records of North Staffordshire and the Peak District National Park respectively. Both cave sites and barrows are shown. Recovered objects were divided into material classes, which included: metals, lithics, ceramics, and special deposits. The special deposits class was included to cover unique objects or materials such as a sandstone vessel and/or jet beads that were not common among the burial contexts.

A separate analysis based on the occurrence and frequency of internment versus cremation burial was also run. This graphic also appears in Chapter 4. The above figures show the distribution of the different material classes. There is not a fixed pattern in the distribution of all or any of the different materials. The distribution does not show a conscious bias in the deposition of any specific materials towards the copper mines, but a more even pattern of distribution across the survey area.

The difference in the distribution between cremations and internments, although typical for this period, may reflect different specific burial practices within a much broader tradition. The overlapping distributions, and even the presence of these different practices may represent changing patterns over time or, conversely may indicate the use of the same barrows by groups observing different burial practices inhabiting the same landscape. Kitchen (2001) has proposed a level of political autonomy operating within the Peak District during the Bronze Age, within a disarticulated social system that involves different groups each with different specific traditions (reflected in the burial practices).

The barrows may have remained embedded within a series of different routines tied to the exploitation of different resources (i.e. copper mines, farm, and pasture lands).

The barrows on Ecton may also be tied into the ideas of access to, and the maintenance of, the copper mines by multiple groups. Different barrows may have continued to have different meanings possibly even during their construction and use for and among the inhabitants of the regions. The density of round barrows in particular around Ecton may be more indicative of their relative importance than the material within if, as Barnatt (Barnatt 2000) has suggested, barrow burials were not the preserve of an elite. Social groups during the Late Neolithic – Early Bronze Age may benefited from a complex patterns of movement, social adherence, and seasonal use, with different kin systems relying on this flexibility to maintain access to or tenure over specific routes, pasture or other resources.

Initially, the concept of visibility within the Peak District was important in describing the difference in the character of the White versus the Dark Peak. While the moorland of the Dark Peak offer broad horizons and a sense of space that creates a focus on place, the White Peak is more visually restricted with a greater emphasis on movement through and between different places, creating a sense of space. During field walking it first became apparent that Ecton Hill was a key landmark in both environments. There were extremely few locations from which the Hill was not visible. Notably in the Hamps and Dove river valleys as well as the Manifold Valley to the south of Wetton Hill and Thor's Cave. Narrowdale and Gratton hills also obscure the view of Ecton from the south. The primary goal of

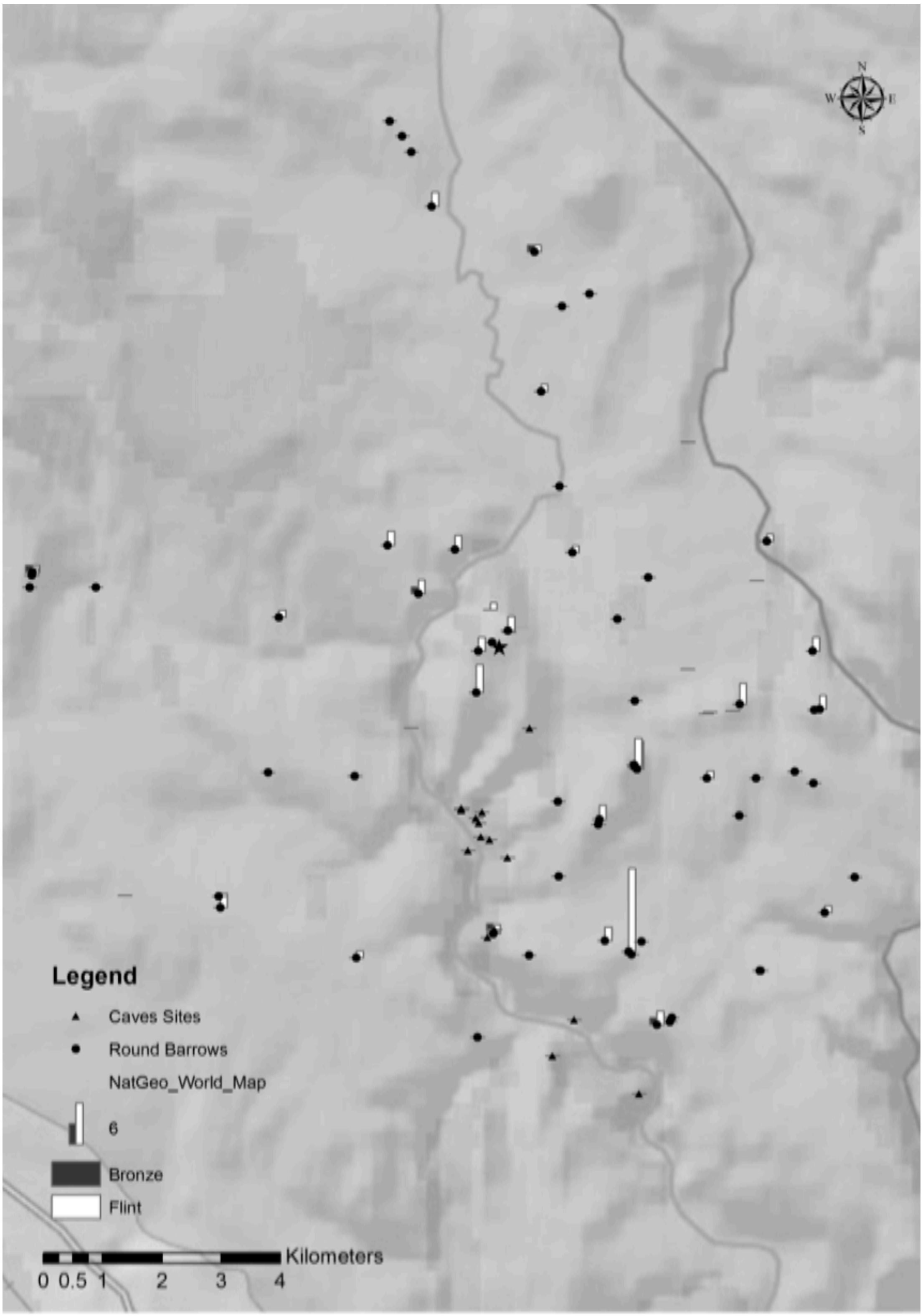

Figure 6. 29 Distribution of metal and flint

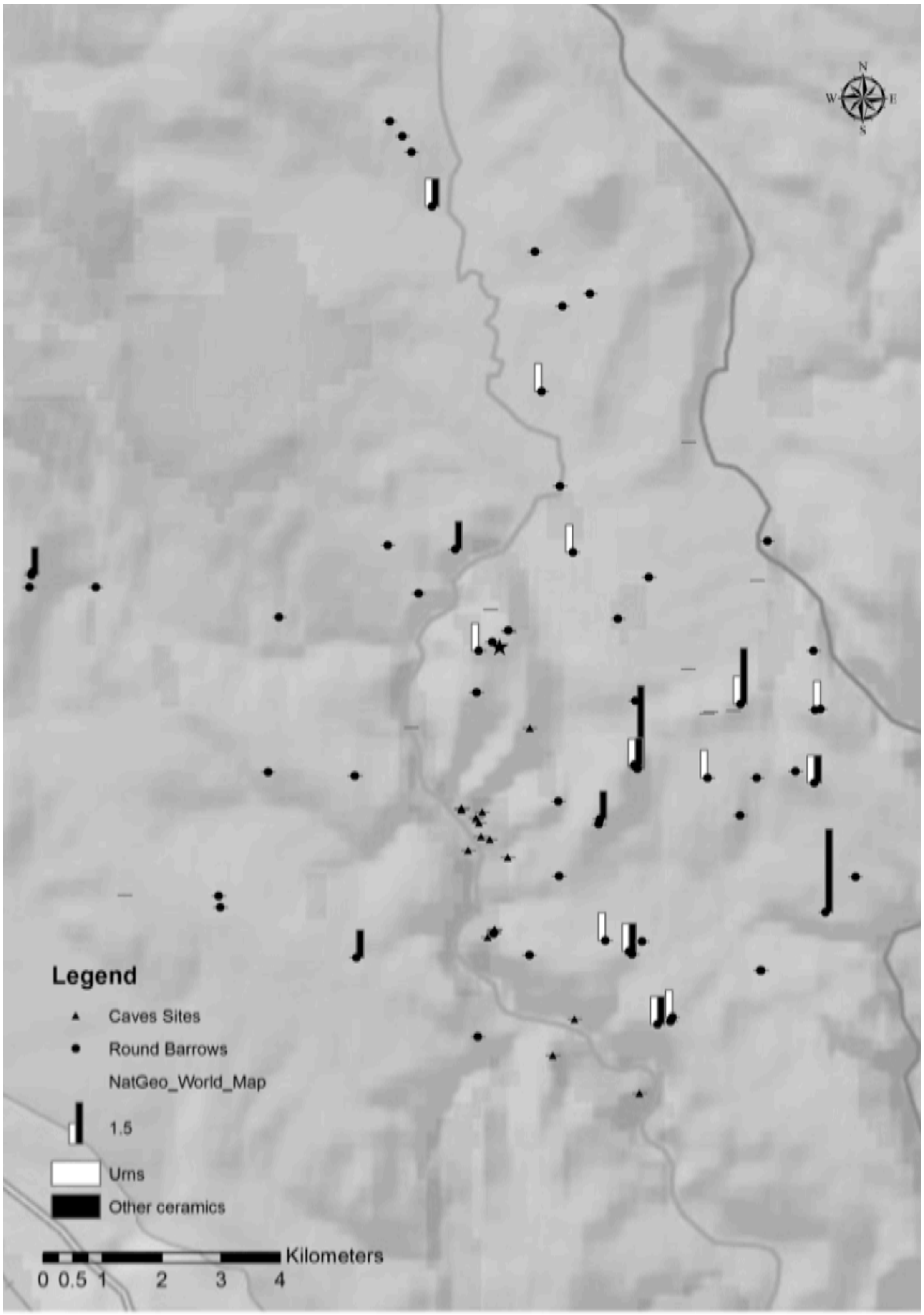

Figure 6. 30 Distribution of ceramics

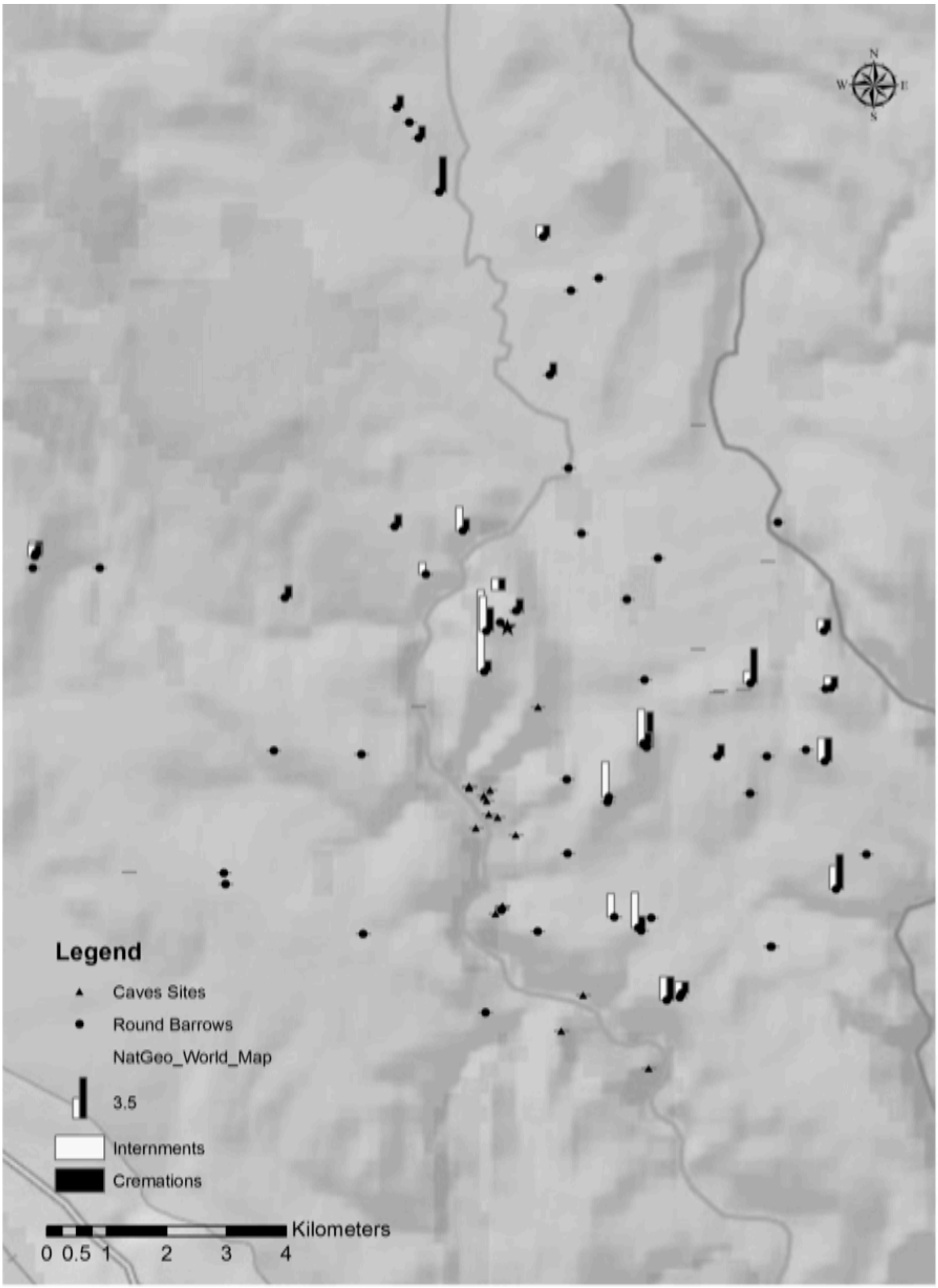

Figure 6. 31 Distribution of burials

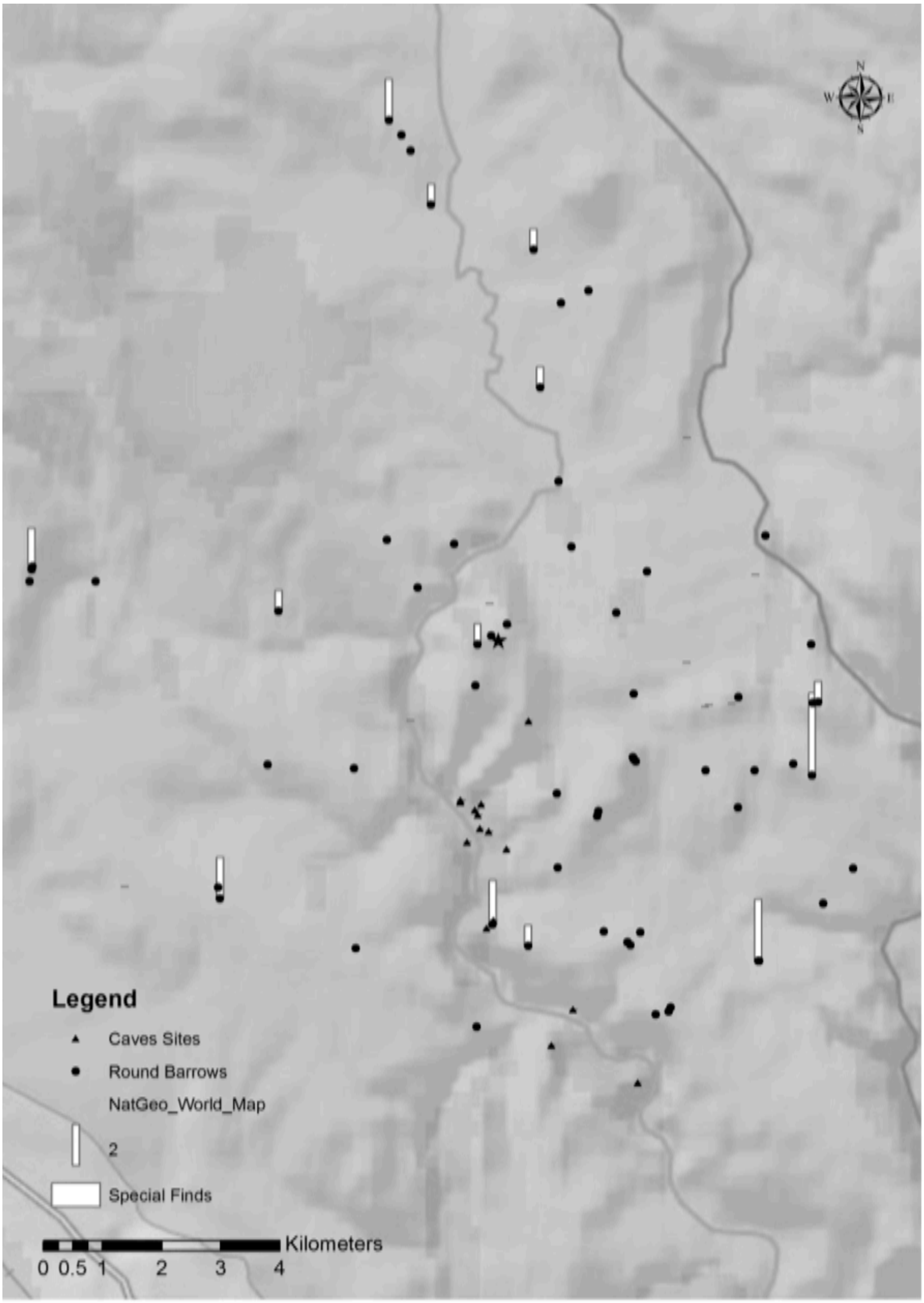

Figure 6. 32 Distribution of special finds

this viewshed analysis was an attempt to find a way to represent the visibility of Ecton within the surrounding landscape.

As the identification and relocation of sites in the field progressed it also became apparent that the location of barrows in particular took advantage of locales with clear lines of site to Ecton. While this is not unusual for the sites in the more open landscapes to the north and west of Ecton it was more noticeable among the hills and ridges south of Ecton, beyond Wetton, Narrowdale and Gratton hills. The viewshed analysis is a tool that is able to graphically display the visibility not only of Ecton within the wider landscape but the inter-visibility, or in the case of the cave sites lack of inter-visibility, between Ecton and specific sites.
Ecton Hill is highly visible within the landscape, whether on a distant horizon across the much flatter expanse from the north and west or in the closed spaces of the limestone plateau to the south and east. Figure 6.36 shows the areas of landscape visible from the highest point of Ecton, which sits on the northwest ridge, above the mines and is occupied by one of three round barrows. The view shed shows blind spots around the base of the hill; however the hill remains very much a part of the landscape despite an inability to see the specific barrows that were the focal point for this analysis.

All of the barrows within this survey area appear to be visible from the hill, and their placement does seem to reference the importance of inter-visibility with Ecton. This is not so with cave sites, which, with the exception of Thor’s Cave and Sycamore Cave, are within the Dove and Manifold River Valleys. Although the above view shed does show Thor’s cave to be visible from Ecton, there is no inter-visibility and the southern landforms of Ecton Hill block the northern extent from view at the opening of the cave. Sycamore cave is also hidden from the barrows of Ecton, as its entrance is open to the east on the back of Ecton. Further discussion of these results can be found in Chapter 7.

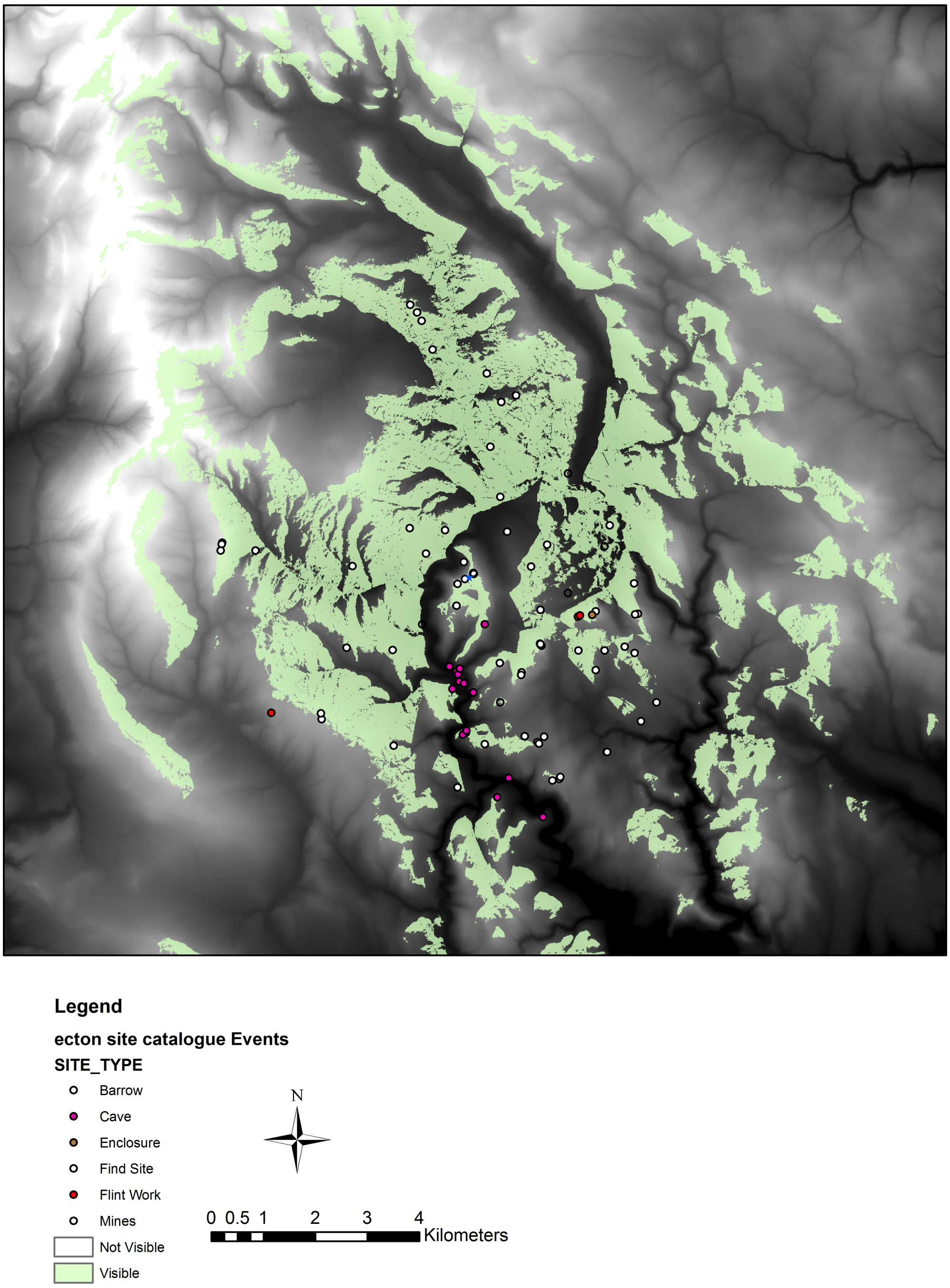

Figure 6. 33 Viewshed from top of Ecton (analysis was performed using the 'calculate viewshed' function provided in the ESRI ArcGIS 9.3 software package).

6.6. Analysis of Collected Material

There was little archaeological material collected during the course of fieldwork. No material was recovered during the first stage of survey. The test excavations resulting from the geophysical and geochemical surveys of the northwest slope of Ecton Hill recovered no metallurgical debris and the quartzite cobble that was found in trench two was turned over the Early Mines Research Group for further analysis and is not covered in this section. There was also no material collected in the second stage of the landscape survey. Pedestrian survey of Ecton Hill did not produce any potential sites, nor was any potential metallurgical debris identified.

The third stage of field survey did result in the collection of crushed calcite and copper minerals. These were recovered from the eroding spring bed on the back of Ecton, labelled site one in figure 6.29 above. A sample of the crushed vein material and copper ore was washed and photographed (see figure 6.40 below). Visual analysis suggested no heat alteration of the collected material and no further analysis was undertaken.

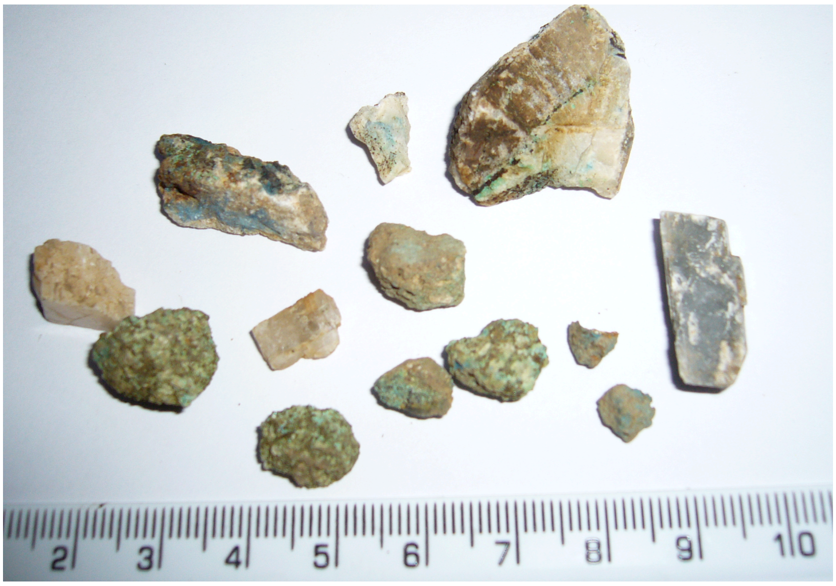

Figure 6. 34 Sample of material collected from Site One.

6.7. Summary

Whilst it is anticipated that evidence for copper smelting may well be ephemeral (Craddock 1989; 1995; Timberlake 2009) it is not unreasonable to expect the combination of survey methods employed at Ecton Hill to be effective in locating magnetic and chemical anomalies, resulting from high temperature activities involved in the processing of copper minerals (Doonan et al. in press; Behar et al 2008). Despite the potential for copper smelting activities to be present in the vicinity of the prehistoric mines, the anomalies investigated though excavation did not produce evidence to confirm the presence of copper metallurgy on Ecton Hill. Those areas subject to geophysical and geochemical survey were considered to have the highest potential for the location of copper smelting activities in proximity to the prehistoric mines, although other likely candidates in the extended hinterland of Ecton Hill do exist.

Smelting sites on the continent have not been difficult to locate with many such sites being reported in the literature (Craddock 1995). It seems that wherever copper mining has been located on the continent, copper smelting has been found accompanying the extraction. This is not to say that smelting activities are always located in the immediate vicinity of mining activity, but that they do appear to be at least visible. The contrast with Britain is significant where the results of the limited field based survey and excavation(Bannerman 2000; Doonan and Eley 2000; Timberlake 2003b; Timberlake and Prag 2005; Wager *et al.* 2002), including that at Ecton, has recovered very little evidence relating to the further treatment of ore. Although it is tempting to suggest that smelting was not performed in the immediate vicinity of the mines scope of the work across Britain has been limited. Evidence of copper smelting was not found on the hillside of Ecton immediately adjacent to the Bronze Age copper workings.

While the pedestrian survey of Ecton Hill did not reveal any further sites relating to possible metallurgical activity, it did highlight the potential for an embodied approach to add to an understanding of movement within the landscape. This includes access to and potential the movement of materials to and from mine workings. Considering possible paths of movement within the surrounding environment may help to target additional survey. The final level of survey identified a possible site relating to a potential metallurgical taskscape, although this site cannot be characterized at this time and has not been excavated or dated. A number of additional copper resources that may have been available in the Bronze Age were also identified. The limestone and gritstone cobbles employed at Ecton are demonstrably available in the vicinity of the mines; however, the more dominant quartzite cobbles are not. The recovery of only a single example of quartzite in the river systems surrounding the mine likely represents an exotic cobble brought in, possibly for mining purposes, but it was apparently never used and either lost or discarded. It is unlikely that this represents locally available fluvial sediment; the absence of any other quartzite identified during the extensive survey highlights the exotic nature of this cobble.

7. Discussion

7.1. The Work at Ecton

Ecton Hill is one of two sites in England with solid evidence for copper exploitation in the Early Bronze Age . The dating of this activity at Ecton, from antler and animal bone, is between 1880 and 1640 cal. BC. Mineral extraction was concentrated in two specific regions of the hill. The first location, likely representing the earliest phase of mining activity, is on the flatter north western shoulder of Ecton, below the summit ridge, where mineralization outcropped at the surface at Stone Quarry Mine and possibly also At the Ecton Pipe, only slightly further west. The second location, slightly further up the hill, is the Lumb, a diagonal opencast like feature extending up the steep western face towards the summit of the hill. Survey and excavation of these features, and the denuded mounds of mining spoil found adjacent, has established their origins, or in the case of the Ecton Pipe - likely origin, in the Early Bronze Age (Barnatt Forthcoming).

Ecton was also the site of one of the most successful post-medieval mines in Britain, with the peak of production from 1760 to 1820 AD. While the historic mining initially began on the flatter northwestern shoulder, where Early Bronze Age mining has been established, the focus for activity quickly moved to the floor of the Manifold Valley. As the mines reached ever deeper it became more convenient and easier to develop points of access closer to the level of the working floors, established in the Manifold Valley. Mining specific development within the valley included: dressing floors, a smelter, and, a little more recently, a stamps yard (Barnatt Forthcoming; Porter 2004).

Surrounding Ecton, the landscape features a number of Late Neolithic – Early Bronze Age sites. These are primarily round barrows although cave deposits are also dotted along the Manifold Valley. Very few traces of habitation or activity have been found among the funerary monuments, making the mines even more relevant as evidence of activity concerned with craft and production. With the density of burial contexts surrounding Ecton one could perhaps argue that the ore extracted was used in the production of grave goods; however, as seen in Chapter 4, very few copper or bronze objects have been recovered from these contexts. Only five bronze objects have been recorded from among the 65 closest barrows, with an additional copper flat axe recovered from Sycamore Cave on the Back of Ecton (Houdmont 1989; 1991). Modern excavation and recording of additional barrows may change this ratio, but the fact remains that the deposition of copper and bronze objects is not well evidenced Late Neolithic – Early Bronze Age round barrows of the Peak District (Barnatt and Collis 1996).

The goals of this thesis were to: investigate the possibility that mineral processing and / or smelting took place in immediate proximity to the point of mineral extraction; examine the surrounding landscape in an attempt to place additional metallurgical activity within the vicinity of Ecton and establish a taskscape relating to the production of copper metal; and to attempt to establish the copper mines within an inhabited Early Bronze Age landscape rather than considering the mines in isolation on an incredibly daunting tabula rasa, with no points of reference for possible coeval activity or habitation.

7.2. Discussion of results

Initial survey of the western slope and shoulder of Ecton identified three features. These had the potential, based on the geophysical and geochemical survey to be related to high temperature conversion of copper ore. Excavation of these anomalous features revealed them to be the result of modern disturbance, likely postdating the termination of the mining at the site at the end of the 19th century. No other features were located that contained the same potential to relate to metallurgical activity. Following the intensive survey, in concert with previous work at Ecton (c.f.), field walking, and excavation of the features identified, no direct evidence of additional metallurgical activity was found on the slopes of Ecton Hill connected with mineral extraction. The possibility remains that the missing evidence was disturbed or removed by post-medieval activity, or that it was missed on the less intensively surveyed edges of the site; however based on the current evidence it does not appear that additional metallurgical activity took place among the mining features.

Further survey of Ecton was also unsuccessful in locating or identifying sites or scatters related to a metallurgical taskscape. However, using the tenets of a *chaîne opératoire* approach, the concepts of movement along different pathways to the mines were addressed. The different aspects of Ecton provide a number of potential routes by which to ascend the slopes and for accessing and using different spaces on and around the hill. Ascending directly up the north section of the west face from the Manifold Valley provides the quickest and most direct access to the mines, but also requires the most physical exertion. Although sheep can be found grazing along this hillside, it may have been too steep to provide grazing or access to the high plateau where cattle could be pastures and graze whilst mining was undertaken. Carrying materials, such as timber, hammer stones or other parts of the mining toolkit, further complicates the ascent of this slope. The same can be said for descending the slope with material, such as extracted ore. Other routes, up the eastern side or through the veiled path on the southern slope, would provide easier access to the top of Ecton, and thence to the mines. If mining and pastoralism were indeed practiced in cooperation (Timberlake 2001b) these alternate routes would also have enabled the movement of animals, alongside people, up onto the central plateau and grazing grounds closer to the mines. They would also make the transport of materials an easier task and may have informed the locations of work camps or other activity sites whilst people exploited the mines and resources of Ecton Hill.

The copper mines of Ecton Hill did not exist in isolation; rather they were one specific point for activity within an active and inhabited landscape. The primary form of archaeological evidence of the Early Bronze Age landscape is the multitude of round barrows that are a common feature of the Late Neolithic – Early Bronze Age . Domestic habitation sites and task specific work sites alike are rare and, when found, very difficult to differentiate from Late Neolithic sites (Barnatt 1996; Barrett 1994; Bradley 1972; Bradley and Hart 1983). However, an association of sites with barrows has been noted elsewhere in the Peak District

(Barnatt 2000). This is not always a direct association, but a connection between communities and ritual monuments provided a possible means of organising and focusing field survey within a larger area. Survey was also targeted at waterways, both permanent and seasonal. This is in large part to an association, noted at other sites in Britain and beyond, between water resources and the preparation of mineral ores. This association is not fixed, but evidence from the Great Orme (Ottaway and Wager 2000; Wager 1997; 2001a) and Copa Hill (2003b; Timberlake 2010)in Britain, suggest a connection as does evidence from Mount Gabriel (O'Brien 1994). This large area survey resulted in the identification of a potential site along a watercourse on the east side of Ecton Hill.

The wider survey of the landscape surrounding Ecton was aimed at addressing the range of other activity and materials that fed into the metallurgical process as much as it was about attempting to identify remains of the metallurgical taskscape. Prior to engaging in the extraction of copper ore, a number of materials had to be gathered and/or prepared. This preparation would have included the making of containers to move the ore and rock out of the mine to locations where it was crushed sorted and ultimately smelted as well as tools for use in the mines and in post mining processing. The potential range from which this material was drawn is exemplified in the hammer stones recovered at Ecton.

Subsets of these tools were fashioned out of local gritstone and limestone, which are available in the Manifold and Dove water sheds. However, the majority of the recovered hammer stones were fashioned out of a non-local quartzite. Survey of the river systems confirmed that this material was not available in the immediate vicinity of the mines. The most likely sources of appropriate quartzite cobbles are the bunter beds that mark the course of the Triassic Budleighensis River. These outcrop on the edges of the primarily carboniferous Peak District and in the Trent River system. The closest identified quartzite bearing deposits occur roughly 20km southwest of the copper deposits of the Manifold Valley.

A further goal of this thesis was to attempt to relate the copper mines to other features in an Early Bronze Age landscape. The initial hope was to be able to establish this connection through metallurgical sites or debris in order to establish some form of metallurgical taskscape. Unfortunately this evidence was not recovered. Another means of establishing the potential place of the mines and their connection to specific features would be through radiocarbon dates. These could be used to suggest at least coeval activity if not an outright connection. Again the majority of barrows in the Peak District, and in the study area specifically remain undated. They were frequently excavated by antiquarians and in frequently re-excavated. Therefore contemporaneous dating could not be established in a meaningful way.

However, the physical location of barrows may suggest connections to the mines. There is an immediately apparent association between the mines and three Bronze Age barrows located immediate above the mines on the western ridge of Ecton. These barrows surmount the hill and feature beautiful nearly 360 degree vistas of the surrounding landscape. Only Wetton, Narrowdale and Gratton hills to the south and southeast block the view. The mining feature known as the Lumb approaches these barrows from below and nearly undercuts the closest one, although there is also a limekiln that interferes and accentuates the physical proximity. These barrows, and Ecton hill itself present potential additional connections to the wider landscape. The viewshed analysis displays the considerable visibility of Ecton within the landscape. While this is not unexpected of such a large feature, the importance of lines of site in the visually restricted area enclosed by the previously mentioned Wetton, Narrowdale and Gratton hills is more relevant, and possibly revealing. The importance of visibility may be referenced to the copper mines as an important site and/or resource, although caution must be urged. Owing to the lack of radiocarbon dates of the barrows in question it is not known whether they were constructed, or in use during the same period as the mines.

Locating the mines among the other traces of the Early Bronze Age landscape highlights their relative importance as a feature or resource. As previously mentioned the three barrows found on the western ridge of Ecton overlook the mines directly. These may represent multiple kin based groups expressing a right to access and exploit the copper mines. These rights may have been established through historical precedent, decent, identity, patterns of use and management, or the long-term investment in the architecture of the mine (Rocheleau and Edmunds 1997). The arrangement of multiple barrows hints at the existence of a larger community that may also be observed in the dense distribution of, and differential practises seen in the barrows across the survey area. These hint at the existence of a disarticulated social system that incorporates a number of smaller groups operating with a level of political or social autonomy and practicing different specific customs, such as burial practices, within a broad tradition. Of the barrows located within the survey area for this project most are visible from the top of Ecton and visually reference the hill in their location. The distribution of material within the barrows, which is dependent on potentially uneven excavation practises, does not show any specific imbalance or bias within the landscape.

The clustering of barrows in the vicinity of Ecton, and specifically the three atop the hill, may represent the use of the mines by more than one group. Rather than expressing ownership, a concept that may not apply to land and resources in a pre-capitalist world, the multiple barrows may be an expression of membership within a wider community with claims of tenure or the right to access the copper mines of Ecton. This wider community may have met on occasions within the vicinity of Ecton to engage in various social interactions and to communally work the mine. Alternatively this wider community may have existed only conceptually, never physically occupying the same location, but co-operatively exploiting and developing the mines. With membership in this wider community came a responsibility to other member groups to maintain the site. This wider community need not have been limited to the living who worked the mines, but may have included a responsibility to past generations, who contributed to the development of the mines and continued to oversee their exploitation from within the associated barrows, and future descendants, the community members yet to come. The maintenance of the site may have included a prohibition on the caching of tools and materials not specifically related to the activities of the mine; although this may also have been a product of the open nature of their use and development.

Following the extraction of ore from the mines member groups may have retreated back to individual domestic sites to further concentrate and smelt the ore. The possible site identified on the back of Ecton may indicate that in at least one instance the ore was further concentrated in the vicinity of the hill, although these remains are not dated and therefore may not date to the Early Bronze Age .

The fieldwork has highlighted the difficulty in identifying archaeological remains from temporarily inhabited sites spread across a mobile landscape. Not all the activities involved in primary copper production need not have led to the same accumulation of material or development of architecture as the mining, which was physically restricted to the location of copper deposits and thus immobile. A successful smelting episode, which may last no longer than a few hours, might be conducted in association with the domestic site or other relevant resources rather than in the immediate vicinity of the mine. Further work on the habitation patterns of the Early Bronze Age may reveal additional information relating to the distribution of activities, including the conducting of metal production.

The use of GIS analysis in this thesis is intended to enhance the understanding of the distribution of Late Neolithic - Early Bronze Age sites in the landscape surrounding Ecton Hill. The concentration of barrows on Ecton Hill in direct association with the copper mines establishes the importance of the site. The density of sites surrounding Ecton also portends the relative importance of this locale in the Peak District. However, this may be over-emphasised, as the dating resolution of these sites is poor with only the broad association of Late Neolithic – Early Bronze Age to connect them. The inter-visibility of, in particular, the barrows with those on top of Ecton Hill re-enforces the connection between these sites and their importance.

Unlike the distribution of sites, the distribution of material does not favour any specific location within the study area. Although relatively few of these barrows have been properly excavated the distribution of material, including exotic items seems to display a fairly even pattern. This could be argued to re-enforce the proposal by Barnatt (2000) that barrows in the Peak were not the preserve of the elite, but used and managed by smaller groups or communities. If the distribution of barrows here, as elsewhere in the Peak District, was linked to specific activity or habitation sites Barnatt (Barnatt 1996b; 1999b) their distribution shows a definite preference for the limestone plateau. While this information was used to inform the field survey, no additional activity or settlement evidence was identified in association to or proximity of the barrows.

7.3. Discussion of method

7.3.1. Mines in the Landscape

The fieldwork at Ecton began with an intensive survey of the hill adjacent to the remains of the earliest mining activity. The combination of geophysical magnetometer survey and geochemical soil analysis successfully identified both concentrations of copper and magnetic dipoles, which may be expected in conjunction as evidence of smelting owing to the concentration of the copper ore and the high temperatures needed to convert the ore to copper metal. Although the excavation of two of these features revealed them to be the result of modern ferrous objects, while the third was a natural concentration of minerals, the combination of survey methods was successful in identifying the anomalous highs, and lows, against the natural magnetic and elemental background of the hill.

A tighter sampling of soil analyses would provide higher resolution; however, it would necessitate an exponential investment in time both in the field and the interpretation of results. Portable X-ray Fluorescence can be used as a field survey method because it is more efficient and responsive than laboratory based XRF analysis, but it still represents a greater investment of time and labour than many geophysical survey methods. Using a higher sampling resolution would be useful in defining the parameters of specific features or sites, but would be unnecessary in survey intended to locate potential sites within the landscape.

Despite the outcome of the test excavations in this case I believe that this combination of survey techniques represents a package well suited to targeting metallurgical activity. The difficulty is in identifying the areas of high potential in order to target this level of intensive survey. There is no certain way of approaching the identification of possibly small-scale sites within a large area. The work undertaken at Ecton and within its hinterland is part of a methodology developed in response to the specific challenges faced in the search for and identification of a dispersed metallurgical taskscape. Clues were taken from the distribution of primary metallurgical sites elsewhere in Europe and the observed association between activity relating to the making of copper and water at other sites in Britain and Ireland. This methodology also attempted to engage with the known archaeological landscape, which is dominated by Bronze Age barrows, but also includes other deposits and cave sites. It was hoped that by situating the mines within this landscape a pattern of habitation or land use might emerge that would highlight the importance of specific spaces or places.

For this project I used a GIS database of known sites, admittedly dominated by funerary sites, to attempt to focus visual survey. This may prove a fruitful means of directing more intensive survey; however potential issues arise in using sites of potentially unknown date or relevance. In the case of this specific project the barrows and sites that were used to focus the survey efforts were only broadly relevant being of Late Neolithic – Early Bronze Age in origin. Future excavation will hopefully provide additional dating information and refinement of this methodology.

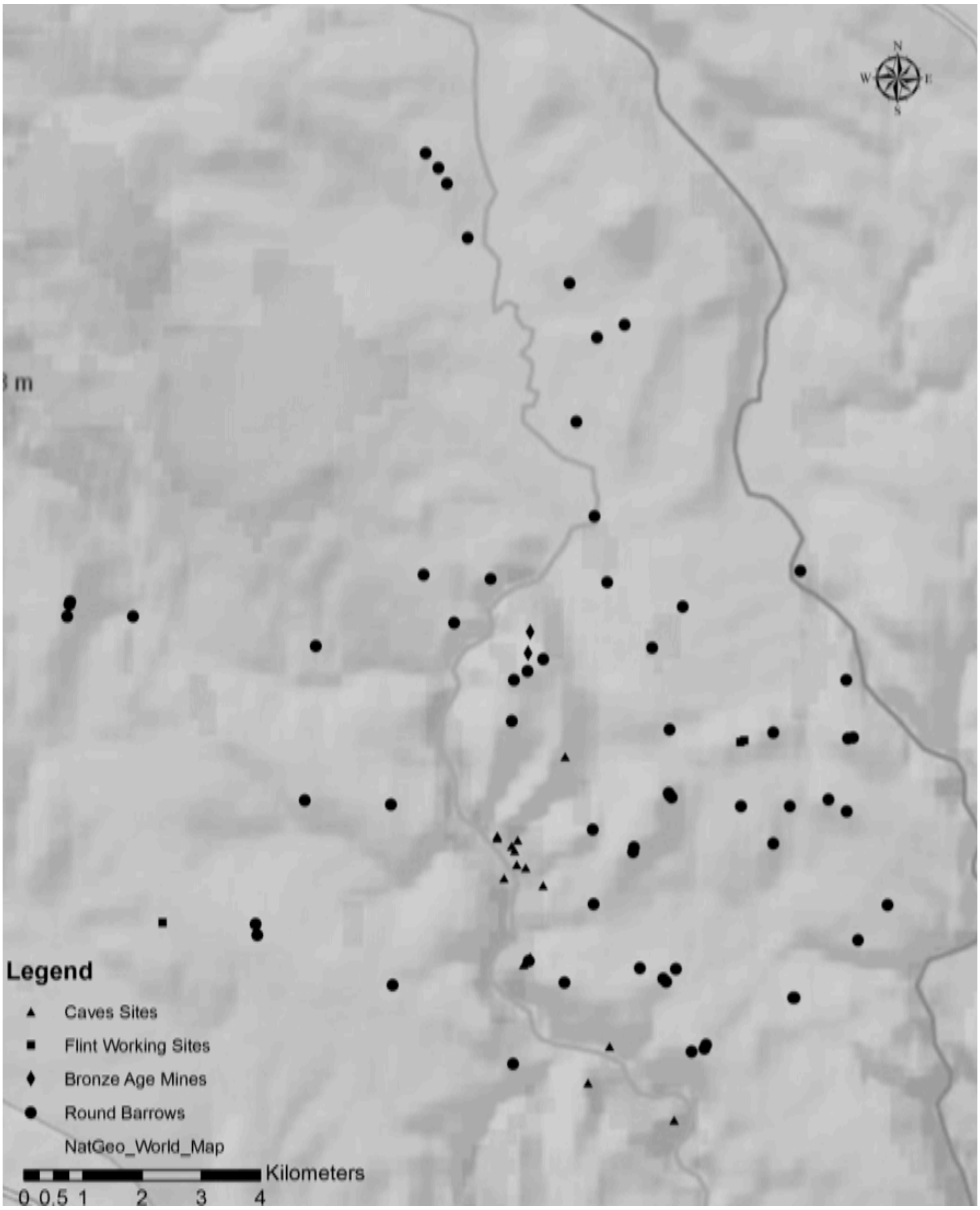

Figure 7. 1 Map of Ecton showing distribution of Early Bronze Age sites

7.4. A Synthesis of Early Bronze Age Metallurgy in Britain

This section revisits the tasks that make up a primary metallurgical *chaîne opératoire* and considers them as historically embedded activities that are socially informed. It does not presume the entrance of new people into a new land, but examines the ways in which the new knowledge may have been adopted or assimilated by existing populations, through associations with more familiar activities. It will examine the making of metal, not as a series of new and unique operations that represent the foundations of modernity (Childe 1930), but as an embedded Early Bronze Age craft utilizing new knowledge. Just as the Neolithification of Britain depended on the acceptance of domesticates and cultural material within an existing world view (Thomas 1991), the adoption and/or spread of metallurgy must also have been accepted, with ideas, modes of production, and materials integrated into established ideologies, inhabited landscapes and the rhythms of life in Britain.

7.4.1. Prospection

While many of the key concepts pertaining to prospection and the identification of metal bearing minerals have already been raised in chapter three, this section will reconsider the task of identifying mineral resources within landscapes that may have been continuously inhabited by mobile or semi-mobile populations over a considerable depth of time. Many copper deposits may not have been unknown to the inhabitants of respective landscapes or environments in the Late Neolithic or Early Bronze Age . As already articulated in chapter three, evidence for the exploitation of copper minerals predating their use in the transformative metallurgical process has been found in other regions of Europe, including the sites that featured extraction of ore for use in the manufacture of pigments and adornments. In Britain, the earliest radiocarbon dates from Copa Hill (Timberlake 2003b) and the association of Mesolithic sites with copper outcrops at Alderley Edge (Timberlake and Prag 2005) imply a previous knowledge of at least some of the copper deposits available in the British Isles (Timberlake 2009), although no objects made from these ores have been recovered from datable contexts nor can pre-existing knowledge be demonstrated for all known Bronze Age or morphologically early copper mines.

Although metal production was fundamentally different from lithic reduction, and represented new knowledge of minerals and their extraction, the concepts underlying the identification and assessment of viable copper ore deposits may have been familiar. The sharing of this new knowledge may have built on the knowledge and traditions of appraising material for lithic production. This may have been in part a visual process, based on the distinctive colours or tarnish of specific minerals (Charles 1967; Ottaway and Roberts 2008), but it may have included physical sampling of the exposure to be evaluated by flaking [lithic] or crushing (Timberlake 2009). Timberlake (2001b; 2002a; 2002b; 2009) suggests that prospecting activities would be a natural complement to pastoralists moving animals around seasonal pasturage, particularly in the highland regions, but it may also have been undertaken alongside any tasks that took members of a community into new or rarely visited parts of the landscape. As copper deposits were found and mines began to develop, the need for the identification of additional outcrops may not have remained as important; however that does not preclude the continued identification of potential copper resources within new or changing landscapes and their opportunistic use by mobile people.

Despite differences between the Late Neolithic and Early Bronze Age in the archaeological record of Britain, notably the arrival of metals and the impact of the 'Beaker Culture', there remain broad similarities, particularly in the construction and maintenance of round barrows and the scarce evidence for settlement and habitation. With the exception of changes in depositional practices (Barrett and Needham 1988; Bradley 1988; Needham 1989) and the acquisition of raw material used in the production of copper and bronze, it is seems that the arrival of metals, and knowledge of their making, may not have dramatically altered life, or inspired sweeping changes in the existing patterns of movement and habitation. The identification of copper ores and other new resources would not necessitate a total redefinition of landscapes, inhabited by mobile populations, but would have added to an existing knowledge of available resources. The new sources of materials may have altered the distribution of the largely ephemeral activity and habitation sites within that landscape, but not the patterns of life that existed. The focus of mining, quarrying or material acquisition may have shifted from outcrops of igneous rocks and flint deposits to those of the new material, but lithic production did continue alongside the use of metals (Edmonds 1995). The changing patterns of the consumption of metalwork beginning with its inclusion in burial contexts is representative of its increasing social importance (Barber 2003; Needham 1989). The distribution of such finds may reflect changes in the movement of populations within the landscape, but the preservation of the overall architecture reflects the continued importance of the pre-existing traditions and patterns of life.

7.4.2. Mineral Extraction

Copper mines are the most thoroughly investigated sites relating to primary copper production in Britain. Through the work of a dedicated group of archaeologists in England and Wales the means and methods employed in the development of large mining sites have been explored at the Great Orme (David 2000; Dutton 1990; Dutton and Fasham 1994; James 1990; Lewis 1990b; 1994; Wager 2001b), Parys Mountain (Jenkins 1995; 2003; Timberlake 1988; 2001), Ross Island (O'Brien 1995; 2004), Copa Hill (Timberlake 1987; 1995a; 1996a; 2003b; Timberlake and Switsur 1988), and Alderley Edge (Gale 1989; 1990; Garner *et al.* 1994; Timberlake and Prag 2005), and Ecton (Barnatt Forthcoming; Barnatt and Thomas 1998). This has been aided by the incredible preservation at Copa Hill (Timberlake 2003b). However, a site-specific focus has prioritized the methods and the materials [or lack thereof] recovered of a single part of the metallurgical process. This section is going to look at the extraction or acquisition of minerals within an integrative approach to metal production in the Early Bronze Age ; including possible justifications for the distribution of known mines, mines as artificially created spaces and the mines within an inhabited and meaningful landscape.

Copper mines are by far the most visible of the metallurgical sites within the landscapes of the early Bronze. The mines are activity specific sites that stand out in a period better understood through hoards and barrows, which represent episodes of deposition, consumption, and concentration. The potential distribution of copper mines is limited only by the distribution and accessibility of copper minerals in the geological environments of Britain and Ireland. The observed distribution of mines including dated mines, morphologically early mines where hammer stones are present, and finds of hammer stones show an apparent bias within the total possible distribution.

Copper minerals are fairly widespread across parts of Britain and while modern mining is determined by the potential economic viability of a given deposit this was not necessarily a concern that pertained to Bronze Age exploitation. Therefore, economic reasons are not sufficient to justify the distribution of mining sites dating to the Early Bronze Age . The current imbalance must be explained in other ways, such as: unknown social or cultural restrictions, geological factors, archaeological biases or taphonomic interference. The exemption of a potential site from Bronze Age exploitation may have been due to reasons of accessibility with social, geographic, and/or geological factors rendering a potential deposit inaccessible. Geologically, specific ore deposits may have been exploited over others because of the ease of extraction or of the processing of the ores. Much of the archaeological investigation of mining sites in Britain has been based on the reports of antiquarians and historic miners; this could have introduced an imbalance in the way in which modern investigation has been targeted and therefore a bias in the overall distribution. Taphonomic factors might include the destruction of sites through the intense exploitation and site development of the copper, lead and tin mining industries, again producing a bias in the known distribution of sites.

Timberlake (2001b) has suggested that the observed imbalance may be an artefact of a conscious and widespread social decision not to exploit the constituents of bronze within the same landscape. This would see tin and gold resources exploited in southwest England while copper and lead would have been drawn from elsewhere. However, there are many other possible explanations for the absence of visible copper exploitation in this region. While very little evidence for copper mining has been recovered from what is now Cornwall, Penhallurick (1986) has collated the existing evidence for the exploitation of tin across the southwest. The rarity of tin across much of Western Europe may have meant that the effort put into exploiting this specific resource could have resulted in an abundance of copper through exchange. The argument that only specific metal resources were developed or exploited within given regions based on social consensus would be dependant the enforcement of socially created embargos and restrictions. If these existed they may have been due to a need or desire to share the benefits and burdens of mineral acquisition, or to re-enforce exchange networks. The natural distribution of metal ores, and copper in particular, provides an opportunity for different populations to become involved in far reaching networks of production and exchange. The enforcement of social taboos on the development and use of resources throughout such a potentially large and interrelated network might be problematic without centralized control or authority.

The evidence for copper extraction may have been buried beneath, displaced, or destroyed by the extensive post medieval exploitation in regions such as Cornwall and southern Scotland. However, the traces of Early Bronze Age mining have been recovered even from Parys Mountain and the Great Orme in north Wales, which were the locations of intense industrial age mining operations. At its height, Parys Mountain, on Anglesey, rivalled even the copper industry of the Cornish mines (Rowlands 1966) and despite the practice of opencast strip mining, resulting in what Craddock and Craddock (1996: 59) have termed a "devastated environment", the traces of Early Bronze Age activity have been recovered through careful survey (Davies 1939; Jenkins 1995; 2003; Timberlake 1990c; Timberlake and Jenkins 2001). Another possibility is that the same level of survey has not been undertaken in all copper rich regions of Britain. This is especially pertinent in the southwest region of England where copper, tin, lead, and gold deposits laying close to the surface would likely have made attractive targets and yet little to no evidence for extraction has been recovered (Craddock and Craddock 1996). This region would have been an important source of, in particular, tin in attaining the remarkably regular levels of tin found in the metal objects dating to the Bronze Age in Britain.

The southwest of England has one of the most intensely developed landscapes dating to the Bronze Age in the Dartmoor Reaves and has been the scene of fairly intense landscape survey (Fleming 1988). However, whereas in other part of the British Isles, and Wales in particular, records of stone hammers and old workings have guided antiquarians and more recently archaeologists to earlier mine workings, no similar records exist from the Cornish mining industry. Craddock and Craddock (1996) discuss the relative importance of hammer stones in hard rock mining as well as their ubiquitous presence on Bronze Age copper mining sites worldwide. The remarkably few reported instances of these tools in specific areas of Britain, and the southwest in particular is remarkable, but should not be used to excuse a lack of modern survey and fieldwork in these areas.

General patterns observed in the formation of known mining sites and their various geologies provide three broad groupings that can be made based on the structure of the mine workings. These types also correlate with the specific geological settings and formations in which Bronze Age mines have developed. Group one features opencast or trench mines. The mines located in the sedimentary environments of the mid-Welsh highlands dominate this group. The second possible grouping features mines that developed subterranean features while the third grouping would include drift or pit mines. Each of these broad structural categories can be directly associated with trends in the surrounding geology of the mines and the mineral formations.

Mine	Geology	Mine type
Alderley Edge	Devonian Sandstone	Pit / Drift Working
Copa Hill	Silurian Grits	Opencast
Park Lodge	Ordovician Gritstone	Opencast
Twll y Mwyn	Ordovician Gritstone	Opencast
Nantyrarian	Unknown Sedimentary	Opencast
Tyn y Fron	Unknown Sedimentary	Opencast
Nant Yr Eira	Ordovician Gritstone	Opencast
Great Orme	Limestone	Opencast / Subterranean
Parys Mountain	Limestone	Opencast / Possible Subterranean
Ecton	Limestone	Opencast / Possible Subterranean

Table 7. 1 Typology of mines by structure and geological setting

The pit mines of Alderley Edge are found in the Devonian 'old red sandstone' deposits with a striking similarity in the mode of mining to the drift workings of Mount Gabriel in southwest Ireland, which are found in the same geological environment (Carlon 1979; Gale 1989; Jackson 1968; O'Brien 1987; 1990; 1994; Timberlake and Prag 2005). The Alderley Edge mines are associated with fire setting and numerous, extensively modified, hammer stones. The mine workings tend to be shallow, extending into the sandstone formation only a few metres in their quest for secondary copper minerals that are locked in sedimentary bands and stringers (Ixer 1994; Ixer and Budd 1998). The mines of the second group, that feature subterranean, or suspected subterranean workings include: Ecton (Barnatt and Thomas 1998; Kirkham 1947; Kirkham and Ford 1967), the Great Orme (Bick 1990; David 2000; Dutton and Fasham 1994; James 1990), and Parys Mountain (Jenkins 1995; Jenkins 2003; Timberlake 1990c) and are found in regions of limestone geology. Fewer hammer stones have been recovered from the mines in this group and, although still present, the use wear shows that a large number of these tools were used in post extraction processing. Finally, the mines belonging to group one, the trench and opencast mines, have a primary distribution in mid-Wales where the geology is a primarily Ordovician sedimentary environment, dominated by shale, mudstone, greywacke, and the Cwmystwyth Grits group (Jones and Frost 2004; Timberlake 1990b; 1992a; 1995b; 1996b; 1996c; 2003b). These observations are general trends only, but may help inform Early Bronze Age mining practices as a social engagement not only with choices informing not only the selection of ores, but the form the mine takes within the surrounding geology.

The development of mineral extraction methods are not uniform across the British Isles, nor is the relative quantity or use of hammer stone tools recovered from mining sites. The heavy modification of hammer stones has only been observed at Alderley Edge (Gale 1990; Pickin 1990), where a full range of they types of hammer stones has been observed. The tools and structure of the mines can be seen to reflect a process of interaction between miners and their environment that includes a consideration of the mineral deposits and the surrounding geology. It may also be seen as an extension of strategies for the acquisition of material pre-dating the adoption of metallurgy.

The mines then should not be considered in isolation, nor should they be examined as the explicit locale for primary metallurgy. They are the source for only one of the resources used in making metal. However, they are also an architectural form resulting from repeated episodes of exploitation. The development of the mining architecture may have had parallel developments in the social sphere constraints on behaviour and depositional practices. Access to the mines may have been shared between multiple groups who were then responsible for its maintenance. The very essence of this shared responsibility may have precluded the performance of additional activity, such as smelting. Other activity that was oriented for the benefit of a specific group, rather than the wider, and perhaps abstract, community may have been performed apart from the mineral source. This could explain the absence of smelting evidence at mining sites. The idea of shared tenure may also been seen as a key factor in the relative sterility of Early Bronze Age mining sites in Britain and Ireland with caution to collect and remove tools belonging to the miner and materials not related to the extraction of ore or the maintenance of the site.

7.4.3. Beneficiation

The parallels between the crushing and hand sorting or separation of ore from gangue and other activity, specifically the preparation of cereal domesticates has already been noted both in this thesis and elsewhere (Giles 2007; Hingley 1997). As explored in chapter three, beneficiation is most visible in the context of mining. This activity may be exempt from a restriction on other activity that is very notably absent from the mining sites because it is in essence a continuation of the mining process. It utilizes the same tool set, and in several cases may represent the reuse of discarded hammer stones (c.f. O'Brien 2004) and does not add any additional material to the mining site, nor does it necessitate further changes to the organization or structure of the site. With potentially limited access, due to spatial restrictions, to the working face of a mine, the initial concentration of the ore may been viewed as an extension of the mining with the larger fragments removed from the mines working surface to a less restricted space to be further reduced and the minerals extracted. It could be a task that enabled the involvement of more individuals than the potentially restricted access to the mines working face might allow.

With the interrogation of the wider landscape, additional sites related to the primary production of metal are coming into focus. This follows the suggestion that further processing and concentration of the ore may have been conducted away from the mine and in closer proximity to a settlement of habitation site made by O’Brien (1994) following the project at Mount Gabriel. The mineral processing site located at Ffynnon Rufeinig on the Great Orme is confirmation that mineral processing was continued at a distance from the mines (Ottaway and Wager 2000; Wager 1997) and may indicate that gravity separation techniques were being employed. The identification of a possible site related to mineral processing and separation in the hinterland of Ecton adds to the possible sites relating to primary metallurgy in proximity to, but not directly associated with, a copper mine and the concept of a metallurgical taskscape spread across a landscape inhabited by a largely mobile population.

Evidence for the metallurgical process remains poorly represented. It is only the mines that have a strong presence within the archaeological record. However, the evidence from the mines portrays a restricted range of activity. The evidence for the earliest stages of mining and habitation at Ross Island could also be argued to fit this pattern. The initial episodes of mining took place in the Blue hole region of Ross island whilst the habitation site, and evidence relating to the possible roasting and pre-treatment of ores prior to smelting, even the possible smelting evidence, is located on the western shelf (O'Brien 2004). This could be seen as a distinct separation of these activities and a closer relationship between the processing and further treatment of the ore with other domestic activities. Sites such as Ffynnon Rufeinig and the potential site on the back of Ecton provide further evidence for the continuation of metallurgical activity at a discrete distance from the mining site. Ffynnon Rufeinig was dated because of the additional material indicating other activity likely also took place in association with this activity. These are not sites with large accumulations of material, but are spreads of crushed vein material and copper staining in the surrounding sediments. The materials recovered from these sites may reflect only a single episode of activity thereby limiting the potential for material to accumulate.

7.4.4. Smelting

The smelting process is the aspect of the primary metallurgical *chaîne opératoire* for which the least evidence has been recovered dating to the Early Bronze Age in Britain. In other parts of Europe, and beyond, slag is an inevitable product of copper smelting. It is the accumulations of slag that form the primary evidence for the conversion of ore to metal. Whilst the structures and furnaces used in the process tend to be made from clay and suffer destruction at the hands of the metallurgists and the elements, the slag is virtually indestructible, surviving to mark the location of smelting.

This strongly contrasts with the available evidence in Britain where very limited amounts of slag have been recovered, or identified, in any Bronze Age context.

The fragments of slag recovered from Pentrywn, in North Wales, are the only known or identified examples of Early Bronze Age copper slag in Britain. Unfortunately this site has been heavily disturbed by later activity. A systematic survey and excavation of the ledge that hosts the fragmentary smelting evidence had, at the time of writing, not been conducted and no additional evidence for coeval activity survives. The material was recovered from within a 'v' shaped pit feature in an eroded road cutting on the Great Orme's Head.

The near total absence of slag in the archaeological record in Britain has led to the proposal of a low or non-slagging smelting method. Craddock and Meeks (1987) originally proposed the concept of a 'primitive' non-slagging technique for copper production in response to the low levels of iron observed in Early Bronze Age copper and bronze artefacts in Britain. This argument cites the lack of contact between molten copper metal and an iron oxide rich slag as the likely reason for lower iron levels (Craddock and Meeks 1987). With insufficient contact between these two materials, the products of an established smelting tradition, the molten copper is unable to absorb iron from slag producing the low levels in the artefacts of the Early Bronze Age (Craddock 1989; 1990b; 1995; Craddock and Meeks 1987). With no additional evidence for smelting emerging in conjunction with the increase in the identification and investigation of early copper mines in Britain, the idea of a primitive process has gained strength (Craddock 1989; 1990b; 1995; Pollard *et al.* 1991; Timberlake 2009; Timberlake and Prag 2005).

There has been a lot of speculation on the ideas and possible methods employed in a low or non-slagging smelting technique (Craddock 1989; Craddock 1990b; Craddock 1995). Experimental recreations have attempted to establish possible processes with marginal success. While they have preformed experimental smelts that have produced very little to no recognizable slag these experiments have also produced very little copper metal in return for the materials consumed (Craddock and Timberlake 2004; Pollard *et al.* 1990; Pollard *et al.* 1991; Timberlake 2005).

(but see also Doonan 2008; Doonan and Hunt 1999). Among the potential issued with a non-slagging reduction process in the Early Bronze Age , based on the lack of copper slag, is the continued absence of copper slag extending well into the Late Bronze. Evidence of copper smelting retains its anonymity thereafter, with no copper slag recovered from the Iron Age or even contexts dating to the Roman or Romano-British period. One may point to the absence of mines dating to the period after the Early Bronze Age as resulting in the continued absence of slag; however, the mines of the Great Orme continued to be exploited into the later Bronze Age and roman inscribed copper cakes have been recovered from north Wales. It is very possible that copper smelting was not being conducted in Britain in later prehistory and that the main source of copper was from either recycling or importing from other regions of Europe. This would explain the continued absence of slag throughout later prehistory and the early historic period and the change in the composition of copper metal through time. This includes the metal types identified by Northover (1980a; 1989) as belonging to distinct groups in the later Bronze Age and the reported increase of iron in copper metal identified by Craddock and Meeks (Craddock and Meeks 1987), for which a change in mineral origin and a change in smelting practises are proposed respectively. However this would not explain the absence for other evidence, notably furnace structures, tuyères and crucibles. The exploration of archaeological sites relating to primary copper metallurgy in the Bronze Age has shown that the paucity of evidence for copper smelting in the Bronze Age does not equate to evidence of absence. Rather, there has been very little exploration of metallurgical taskscapes that may have been diffused across the landscape beyond the mine.

The spread of a developed and successful, if poorly understood, smelting method across Britain enabled the early miners in new regions and landscapes to exploit copper minerals mined from the Early Bronze Age copper mines. The smelting method may have changed little during the Early Bronze Age simply because it was effective although social influence may have also impacted the process. If smelting was conducted in proximity to habitation sites, rather than at the mines, it may have been open to members of the community to participate in the process or even conducted as a public event. If the process was open to the community there may have been little scope for experimentation and thereby changes to the smelting practices. If the methods were effective there may have been little desire or need to implement change.

7.5. Final Observations

During the research, fieldwork and analyses conducted in connection to this thesis I have encountered concepts and information that have led me to formulate two alternative ideas. The first is about the conceptual understanding of mines as both archaeological sites and as inhabited, active places within a similarly vibrant landscape. This idea is explored in the section below entitled Mines as Architecture. The second section presents an admittedly speculative alternative to more common methodologies for Early Bronze Age copper smelting in Britain. This alternative is based on the analysis of the Pentrywn slag from North Wales and its apparent similarities to the reported qualities of the slag recovered at Ballydowny in Ireland.

7.5.1. Mines as Architecture

With the recognition of different trends in the structure and formation of mine workings they begin to transcend simply a spot for the extraction of resources. It becomes possible to understand the mines in terms of architecture, similar to Neolithic and Bronze Age monuments above the surface. By this I do not mean to suggest that copper mines were consciously designed and constructed, but that they became places where individual and/or group efforts continually modified the space investing in and adding to the sense of place. Through a long period, perhaps even generations, the continual reuse and modification of the mine, through the extraction of and, in cases such as the wooden launders at Copa Hill, addition of material in response to need. The unique space of the mines is one where place is created through excavation and the removal of material rather than through the accrual of material and its use in construction. The mines are created in order to access and extract copper ore and as such they follow the faults and mineral veining through a geological setting as much as possible. However, they are not uniform in their development with different strategies adopted in the structure and configuration of the mine in response to the mineral formations and geological surroundings. This can be seen as a choice on the part of the miners made through their interaction with the local environment and geology. The use of this space may also be informed by pre-existing local strategies for the procurement of materials and possibly even through depositional practices in caves and subterranean contexts. In conceptualizing the mines in this way it also becomes easier to understand them as sites of activity and specific locations within an inhabited landscape.

The architecture of the mine provides a very real map of the access, movements, and actions of the miners and informs the visitor even today on the appropriate ways of being and moving within the space. Mining began in many places as the collection of minerals from surface outcrops, forming parallels with the collection of other materials or agricultural activity. Much like the harvesting of crops, this surface collection remained connected to the landscape. As some mining architectures developed this characteristic was retained. The wide bedded mineralization of Alderley Edge (Carlon 1979; Timberlake and Prag 2005) may have provided access for multiple individuals to exploit the working surfaces of the mines simultaneously. However, as many of the larger mines developed they delved deeper, forming trenches and narrowed restricted spaces, even subterranean passages and chambers. These became concealed from the landscape and were hidden beneath it. The mines and mining moved from open structures and visible activity to closed and restricted spaces were access might have been limited. The mine workings at Ecton changed the landscape, in particular at the Lumb as the undercutting and collapse of semi-subterranean workings created a visible scar on the hillside.

By entering these spaces it is possible to emulate some part of the experience of the individual and in effect impart a dynamic aspect to that space. This is perhaps where the connection through an embodied existence expounded by a *chaîne opératoire* approach is the most tangible. The mines, like other architecture, direct the movement of visitors and workers alike. In opencast mines the sidewalls grow as the trench deepens creating avenues that direct movement. In the case of the subterranean mines, as at the Great Orme and possibly Parys Mountain and Ecton Hill, the workings very literally guide the individual through an underground world of passages and chambers following the path of Bronze Age miners. Through a shared corporeal existence it is possible to understand the movement of the miner through these restricted spaces into or out of an open cast trench, pit mine, or subterranean gallery.

The mining sites are not limited to the hollow created through the removal of material, but include the spoil mounds, that are a result of that removal, and the working spaces where other tasks, such as ore preparation, may be undertaken. This includes a level of spatial organization that may be seen to change as different areas of the site are repurposed over the duration of activity at the site. This can be seen at Copa Hill with the shifting locations of spoil deposition and the re-excavation of the front access of the opencast (Timberlake 2003b). It is also apparent at Ross Island with changes in the active mine workings, the distribution of processing debris and the locations of potential roasting or smelting structures over time (O'Brien 2004).

The material characteristics of the mineralization and host geology are the most apparent properties relevant to the development of a mine, but as the architecture of a mine develops additional considerations may become necessary. As conditions within the space of the mine changed, becoming more restricted enclosed or perhaps descending underground, so would conditions that may be taken for granted in more open spaces. One example is the problem presented by the accumulation of water and the drainage of mines. The wooden launder recovered at Copa Hill was used to direct the water and drain the deepening opencast (Timberlake 2003b). It represents a solution used to suppress one of the characteristics of the environment with which miners interacted at that site. Miners would also have had to contend with another set of environmental conditions while working in the subterranean passages and chambers. The absence of natural light in the underground workings meant that miners either had to function in darkness or introduce and maintain sources of artificial light. Airflow may never have become a problem in the underground galleries, but the combination of heavy labour and combustion, through advance fire-setting or lighting the space while work was underway, may have taken a toll on the air quality. Architectural developments such as the closing off of disused galleries at the Orme (Lewis 1990b; 1994), or the intermittent shafts to the surface from possible prehistoric workings at Parys Mountain (Jenkins 2003) may have been means of controlling the airflow and quality within these constrained spaces. These factors betray a deeper consideration of place and the material conditions involved in inhabiting and working within these spaces.

Parallels can be drawn between the use of space within the mines and in natural caves highlighting the artificial nature of the distinction between natural and anthropogenic features. The restriction of access and possibly movement and visibility is a common feature of many mines and caves. The similarities between these contexts may have informed the behavioural practices and in particular the apparently stringent, albeit remarkably different, depositional practices observed within the mines. Metal objects have recovered from where they had been carefully deposited in many of the natural caves around Ecton (Chamberlain and Williams 2001; Houdmont 1989; 1991) and similar contexts farther afield (Barber 2003; Barnatt and Edmonds 2002; Needham 1989). The primary act in mines was the extraction of material used in the making of metal and deposition appears to have been very restricted, with only material or tools relating to the act of mining recovered from these contexts. Metal, although apparently used in at least some of the mines (Lewis 1994; O'Brien 1994; Timberlake 2003b), was expressly not included in any of the caches or deposits that included tools of wood, stone, antler, and bone.

These depositional practices may allude to a much deeper social meaning attached to the mines that may have informed additional activity at the site. They are places that were created and inhabited by Bronze Age people engaged in the act of mining and in which may have existed specific guidelines for appropriate behaviours and activity. The mines are not just sources of raw material, but places imbued with specific meaning through an investment of labour, materials and continual re-working. They may have been part of a wider social network wherein a number of member communities shared tenure of the site including the right to extract ore and the responsibility of maintaining the architecture of the mine. This wider community may have met to physically work the mines together where access was more open, or it may have existed only conceptually with groups dispersed throughout the landscapes exploiting the mines as part of their own rhythms of movement. However, the social construction of place within the mines may have exerted considerable influence on the behaviour and activities practiced within the context of these sites.

Membership within this community may have been open or dependant on kinship, descent, or contributions in materials or labour. This may have been expressed through the accumulation and transport to the site of necessary materials, such as the hammer stones that may have been brought from a considerable distance (Craddock and Craddock 1996; Pickin 1990; 1999; Timberlake and Craddock 2003), or in the investment in the site, such as the wooden launder at Copa Hill which represents a considerable investment of labour. Membership to a wider community may also have been expressed in the mortuary practices of member groups. The density of round barrows at Ecton and their apparent association with the mines, three barrows are located on the western ridge of the hill, immediately above the copper mines (Barnatt and Collis 1996; Bateman 1861), express a particular importance of this place within in its surroundings. The apparent importance of the hill is also expressed through its inter-visibility with the surrounding round barrows and in particular those among the far more visibly restricted limestone hills south and east of the mines.

7.5.2. An Alternative smelting model

Analysis of the minimal slag recovered in Ireland and Wales may hold further clues to both the method of smelting, and potentially the poor preservation of the slag produced in the archaeological record. Slag has been recovered from two sites dated to the Early Bronze Age : Ballydowny, in County Kerry, Ireland; and Pentrwyn on the Great Orme headland, north Wales. Analyzed samples of slag from both sites have been shown to be rich in iron, which is not surprising based on the types of ore being mined in the period. More surprising is the high levels of calcium and low levels of silica observed in the sample from both sites. Where as most copper slag is rich in silicate, due in large part to its common use as flux with iron rich ores, the much lower levels observed in the Irish and British samples may be significant. Salter (unpublished report) has already noted the similarity between the remains of the modern, Mitsubishi process and the Bronze Age samples. This process uses a calcium oxide, or lime, flux, rather than silica in achieving the separation of copper from mineral solution in the ore (Davenport et al. 2002). Calcium is readily available at a number of dated Early Bronze Age mines, as calcite within either the primary vein material that hosted the copper ore, or in the surrounding limestone geology.

If calcium oxide, or lime, were used as a flux (O'Brien 2004; Salter unpublished report) it rely on roasting the readily available calcite [CaCO3] transforming it to calcium oxide, or lime, [CaO] which would then be used in place of a silica rich flux [SiO_2]. It may have been possible to use crushed calcite with the smelting hearth making the necessary transformation, but this would need to be tested experimentally. A silica flux reacts with the iron in the ore under high temperatures to produce a silica rich iron oxide slag and copper metal (Bachmann

1982; Davenport et al. 2002). The slag continues to absorb iron oxide, rapidly increasing the melting point of the slag as the iron content increases, until the it forms a crust of solid magnetite [iron oxide] that will impede further conversion (Davenport et al. 2002). The slag formed in this process will include some copper prills, but ultimately the higher melting point would render this material beyond the capabilities of prehistoric conversion and may be considered waste (Bachmann 1982). Using a calcium oxide flux forms a much different slag that may include a higher percentage of copper alongside iron and of course calcium oxide (Davenport et al. 2002). This solution has a low viscosity, which is ideal in slag formation, and remains liquid in a range of environmental conditions and at lower temperatures for longer (Davenport et al. 2002). The lower melting point and higher potential retention of copper in the slag might have meant that such material was, or could be kept by the smelter, both for the potential recovery of the remaining copper, but also as a 'slag starter' for future smelts.

A ready formed and usable slag may have been a valued addition to a smelt alongside fresh ore and flux, as it would have facilitated the formation of slag in the new reaction and thus the separation of copper. Introducing a developed slag alongside new material could be seen to make the process a conceptually continual, albeit spatially or temporally disarticulated, process. The smelting process would not be tied to a single location within the landscape, but could be moved, travelling with the group. The slag from previous episodes of smelting could have been introduced into the furnace or crucible of each subsequent event. Smelting then could become a mobile craft and seen to compliment a mobile or pastoral settlement pattern, observed in many regions of Britain and Ireland during the Early Bronze Age , rather than inflicting change on the life ways and social organization of the people who adopted copper metallurgy.

Calcium oxide slag is not as indestructible as a silica-iron slag. It could be reprocessed, making it potentially valuable within the Early Bronze Age . If such a slag were produced it may not have been abandoned as waste, but kept and reused or re-smelted to recover additional metal. If it was ultimately abandoned, having served its purpose and being left deprived of copper, a lime-based slag is soluble in water (Davenport et al. 2002). When introduced to water the calcium oxide is converted to calcium hydroxide and ultimately to calcite while calcium sulphide, if present, is converted to calcium sulphate and ultimately is dissolved, leaving only iron rich sand and calcite (Davenport et al. 2002; Salter unpublished report). While such an explanation of the impoverished archaeometallurgical record is a possibility, there remains a lot of landscape to be surveyed before an explanation for the absence of evidence becomes necessary.

8. Conclusions and Future Work

The Late Neolithic and Early Bronze Age inhabitants of this region likely took part in a complex pattern of seasonal use and movement across the landscape. Specific sites, or spaces appear to have been marked out by cairn fields and/or barrows that may have expressed tenure or access to specific resources or places by one or more smaller groups that co-existed within a wider social system. There may have been a number of smaller groups who, whether in isolation or direct co-operation, contributed to the development and maintenance of the copper mines of Ecton. Materials associated with the task of mining have been found at the mines, which are otherwise devoid of Early Bronze Age material culture, implying a social consensus on the appropriate use and deposition of material at the site. Evidence for smelting has not been recovered from the mines at Ecton, nor has it been positively identified within a wider survey area; however this does not intimate the use of a low or non-slagging means of copper production as the limited survey was also unable to identify evidence of habitation dating to the study period. This remains in keeping with the archaeological record for the Early Bronze Age across Britain and Ireland, which is dominated by visible mortuary architecture and largely invisible traces of life.

The primary production of copper was a dynamic process that incorporated a number of resources. The arrival of metal production with its sequence of operations does not represent an entirely new *chaîne opératoire*, nor does it enter into an empty landscape. Rather, it is adopted and adapted by people living in an area with which they were likely very familiar, perhaps even with pre-existing knowledge of mineral deposits. The integration of the metallurgical craft may have benefited from parallels with existing tasks, such as quarrying and cereal processing. The pyrotechnical aspect of smelting may not have been wholly unfamiliar either, having precedent in ceramic production and even cooking, but did add a new dimension as the smelting hearth likely depended on forced air using a blow pipe or bellows, and had to be constantly attended.

The copper mines represent an immobile position within an otherwise highly mobile landscape much like the Neolithic flint mines and quarries, which took on special meaning, and may have contributed to their sense of place and their relative importance within the landscape. The collection and preparation of materials for the metallurgical craft drew on resources dispersed across a wide landscape. The post extraction treatment and smelting of ore and refining and secondary production of metal may have mirrored the collection of resources either consciously or as an unintentional consequence of Early Bronze Age life ways. The special organization of metal production may have reflected patterns of contemporary settlement away from the mine.

Rather than being seen as distinct or wholly unique from pre-existing activities, the primary production of copper needs to be recognized as historically and socially embedded activities. Metallurgy did not arrive into empty landscapes nor was it accepted blindly, but was purposefully adopted by existing populations that lived in established landscapes. Early Bronze Age metal production should be investigated as an extension of activities re-tasked to a new craft.

The negative results from the fieldwork undertaken at Ecton underscore the difficulty in interrogating large landscapes. The methodologies; however showed promise and hopefully with refinement can be adapted and usefully re-employed here and in other landscapes with the potential for the conduct of Metallurgical activity. The negative result of the intensive geophysical and geochemical survey was not a flaw in the methodology, but because of the absence of smelting activity within the survey area.

8.1. Future Work

The potential site in the vicinity of Ecton needs further investigation. The possible processing site located at the base of the eastern slope should be excavated in an attempt to establish a date and quantify the activity at the site. It may be beneficial, in advance of excavation, to use a combination of geochemical and geophysical survey on these sites to establish their extent and any relevant features in order to target investigation. Additional survey around Ecton, although further from the mines should also be carried out. The application of a targeted programme of geophysical and geochemical survey in the hinterland of the Ecton mines may shed further light on the proximity additional metallurgical activity.

Methodologically, future work should examine the current ideas of metallurgical production in the Early Bronze Age in particular, in light of coeval evidence for other activity and habitation. The well-known Bronze Age copper mines are a fixed and immobile point within what may have been a largely mobile landscape. Some sites may have been opportunistically exploited in a single event (O'Brien 2003); however, others represent a significant investment of labour and materials over successive episodes of extraction, perhaps covering generations of Bronze Age exploitation. These sites have remained remarkably sterile with material remains that relate almost exclusively to the extraction of ore or the development and maintenance of the mine architecture. Moving forward, archaeological investigations of primary metal production need to consider a wider network of interrelated sites rather than focusing on a single resource.

Future work should also consider experimental approaches to smelting. Not only does participation in smelting experiments greatly increase the appreciation of the practice, but provides experience with the types of materials and remains that are expected at copper smelting sites. I also believe that experimentation with alternate methods of smelting may provide additional insight into the myriad of choices available to metallurgists and the ways in which a Bronze Age smelter may have dealt with different materials.

9. Appendices

9.1. Technical Report

Introduction

Ecton Hill is located on the Derbyshire/Staffordshire border and has been the focus of copper mineral exploitation for millennia (Barnatt and Thomas 1998). Whilst finds of stone hammers and an antler pick radiocarbon dated to 1880-1630 BC (2σ) support the contention that copper was mined at Ecton during the Bronze Age, there has, so far, been no evidence of copper production at Ecton. The paucity of smelting evidence at identified Bronze Age mines is also true at a national level. Evidence for prehistoric copper mining is now recognised at numerous sites (Timberlake 2003), yet, evidence for copper smelting has proven to be elusive. The unique geological conditions at Ecton coupled with the character of later exploitation suggests that Ecton has good potential for preserving evidence for earlier episodes of copper smelting in the vicinity of mining operations.

This report details the results of geochemical and geophysical surveys which were undertaken to identify potential copper smelting sites at Ecton Hill. Whilst clear evidence for copper smelting in England is lacking, fragmentary or ambiguous evidence for copper smelting has been forthcoming from other sites in the British Isles, namely, Ross Island (O'Brien 2005) and the Great Orme (Roberts 2003). Importantly this evidence has been found in the vicinity of proven Bronze Age mines. This is an important point because as it is an underpinning assumption of this study that copper smelting activities took place in the vicinity of ancient mining operations. Further it is assumed that the smelting of copper minerals employed a technology which relied on elevated temperatures being contained in small ceramic or stone built structures. It is hypothesised that such structures can be detected by magnetometry survey as discrete dipole features and can be expected to be associated with elevated copper levels in the soil matrix.

Methodology

Prior to geochemical and geophysical survey being undertaken a systematic walk-over survey was undertaken to identify any evidence which could possibly be attributed to ancient smelting activities. Survey concentrated on likely topographic features and areas in and around suspected areas of prehistoric mining. Since no evidence of smelting was discovered during walk-over survey, grids for geophysical and geochemical survey were chosen to cover a wide range of environments encountered on Ecton Hill (see Figure 1)

Two survey techniques were employed in the investigation of Ecton hill. The primary technique used was magnetometry survey using a Geoscan FM36 Fluxgate gradiometer. In addition, a geochemical survey was undertaken using a Niton XLT hand-held portable XRF (pXRF) analyser. Both surveys were undertaken on the same grid areas.

Magnetometer Survey
Magnetometry was considered to be the method most suitable for the survey on account of its ability to detect the thermoremnant signatures expected of metallurgical features. A Geoscan FM36 magnetometer was used to collect magnetic data at 0.25m intervals from survey lines separated by 1m within 20m grid squares. When working on steep slopes, survey orientation was undertaken so that traverses could be made perpendicular to the gradient. Due to difficult topography each reading was obtained using a hand trigger. Wind conditions mean that many grid points needed to be re-sampled.

Geochemical Survey
Geochemical survey was undertaken at 2m resolution for Areas 1-3 and the most northerly 20x20m grid of area 5. The remainder or Area 5 and the total of Area 4 were sampled at 5m resolution. Soil cores were taken using a purpose-built corer with a 6cm diameter. All cores were removed from the corer with care taken to avoid compression of the core sample. The face of the sample was dressed using a sharp blade to provide a suitable surface upon which to conduct analysis. Each determination was made in the B horizon or in the lower portion of the A horizon where a B horizon was not attainable (this was rare). Analysis times were determined to be most appropriate at 30 secs. This allowed satisfactory results at the highest sampling resolution. Calibration and standard checks were undertaken periodically throughout the survey to monitor drift and contamination. Geochemical survey employed multi-element analyses but for the sake of this report only copper is reported. Instrumental parameters are included in appendix A.

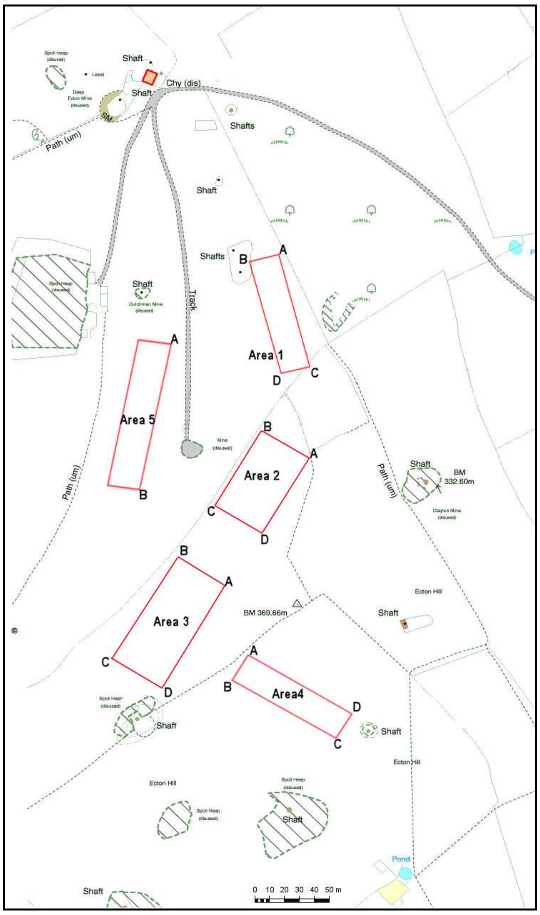

Figure 1: The location of the survey areas (red rectangles)

Results

The results of geophysical and geochemical survey are discussed in the following sections. Greyscale plots of geophysical data collected from all areas are presented along with colour plots for geochemical survey.

The surveys were notable for the absence of any apparent archaeological structures in any of the areas surveyed although there were small, discrete anomalies in several survey areas (see below).

Geophysical Survey

Area One

Area One extends along the northern flank of Ecton Hill. The Area (Fig 2) is 20mx80m and continues the area surveyed by English Heritage in 1998(Bray and Horsley 1998) in a south-easterly direction.

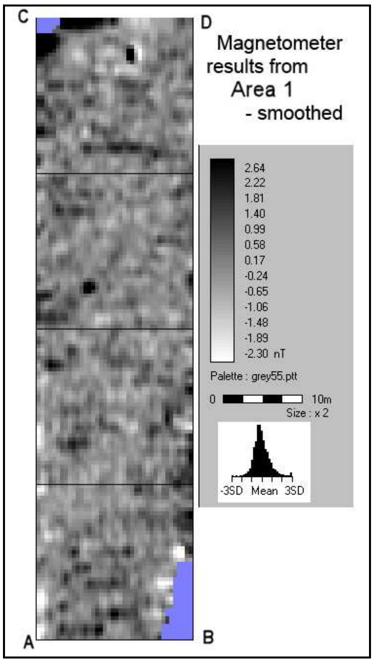

Figure 2: Results of geophysical survey in Area 1

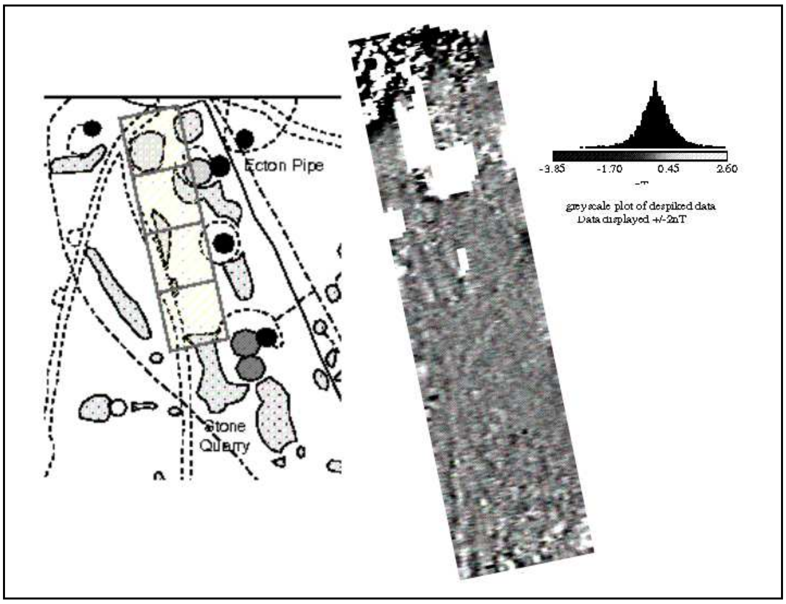

Figure 3: Results of the EH 1998 survey and its relative position.

The only notable anomaly from this latest survey is the weak dipole anomaly in the most south easterly grid. This is located in close proximity to the wall and is associated with significant spoil heaps and mining activity. The ground is much disturbed in this area by spoil heaps and pitting and it is likely that this anomaly is associated with this activity.

Area Two

Area two was located on the sloping ground to the north-east of the area known as 'The Lumb'. This area is considered to be good candidate for prehistoric mining activity. A total of six 20x20m girds were surveyed giving a total grid measuring 60mx40m. Area Two included part of the area surveyed by the EH team in 1998 (Bray and Horsley 1998) (see Figure 5 below).

The survey reported here shows a significant dipole anomaly (**A**) in the centre of Area Two (Figure 4). This correlates with the location of a similarly significant anomaly identified during the 1998 survey. It was suggested by the EH team that the dipole anomaly was unlikely to represent a kiln-like structure as it differed significantly from known examples. However, the anticipated signature from a copper smelting furnace is fundamentally different from that of a collapsed ceramic kiln. Reinterpretation of the original data suggests that this anomaly still has the potential to be a candidate for further investigation.

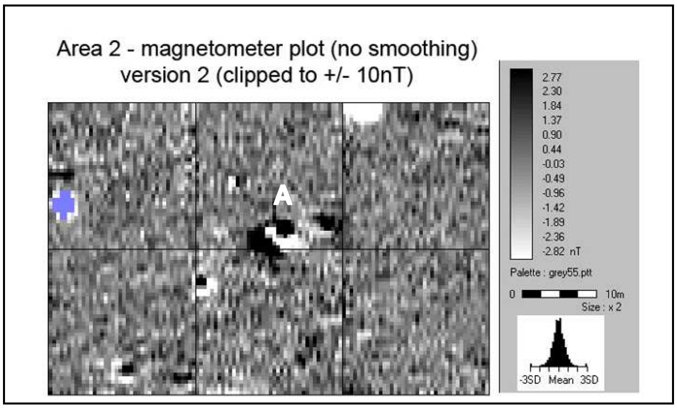

Figure 4: The results of geophysical survey in Area two

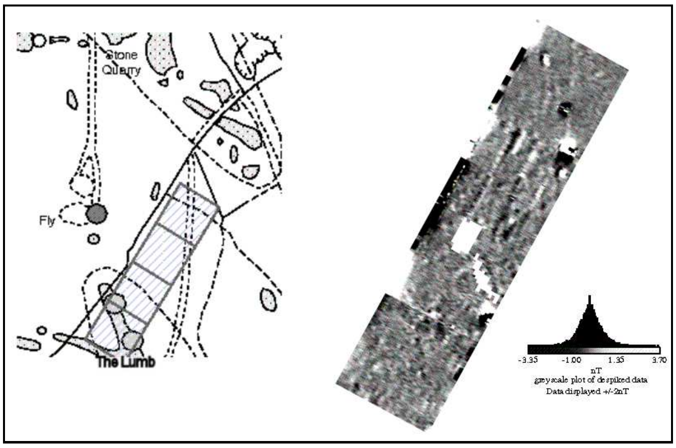

Figure 5: Location and results of EH survey from 1998 showing the significant dipole anomaly.

Area Three

Area Three is adjacent to Area Two and is located on the sloping ground to the south-west of the area known as 'The Lumb'. A total of eight 20x20m grids were surveyed giving a total grid of 80mx40m. No survey was undertaken by EH in this area in 1998. Results from this survey are shown in Figure 6. The survey is notable for being devoid of any extensive archaeological features although there are anomalies which are worthy of consideration.

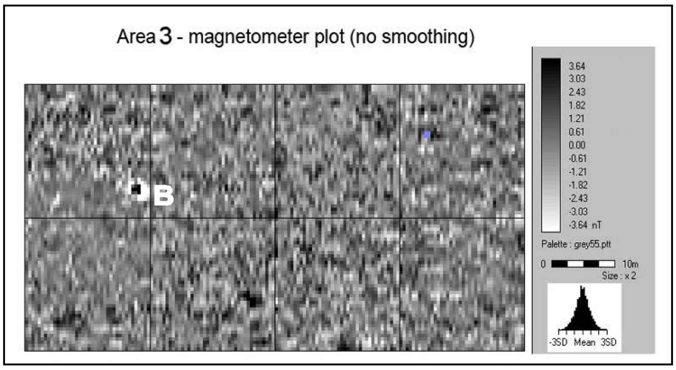

Figure 6: Results for geophysical survey in Area Three

Similar to the anomaly noted in Area Two there is a significant dipole anomaly in the top left hand grid (**B**). Although smaller than the dipole feature identified in Area Two it is a well defined anomaly that broadly fits the criteria for a potential pyrometallurgical structure.

Area Four

The grid in Area four extends south-eastwards from the brow of Ecton hill over level ground away from the trig point. A total of four grids were surveyed amounting to a total area of 80mx20m (Figure 7).

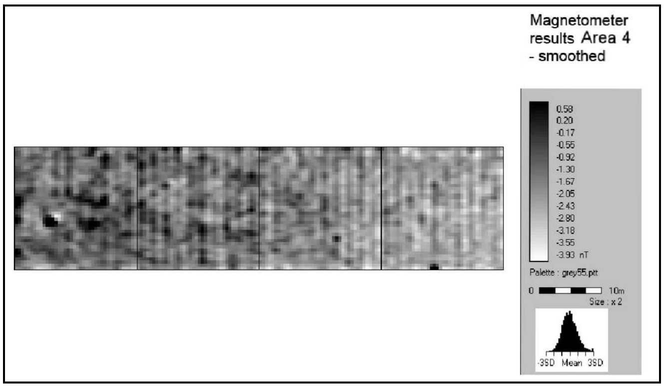

Figure 7: Results for geophysical survey in Area Four.

Again the survey is notable for the lack of any significant archaeological features although there is a small dipole anomaly noted in the most westerly grid. This anomaly is not of the same magnitude of those noted for Areas Two and Three and it is located close to the path which extends across the ridge of Ecton Hill. It is probable that this anomaly relates to a ferrous object.

Area Five

The grid in Area Five extends approximately N-S immediately below Fly Mine. A total of five 20x20m grids were surveyed providing a total survey area of 100mx20m. The results from the magnetometry survey of Area Five are shown in Figure 8.

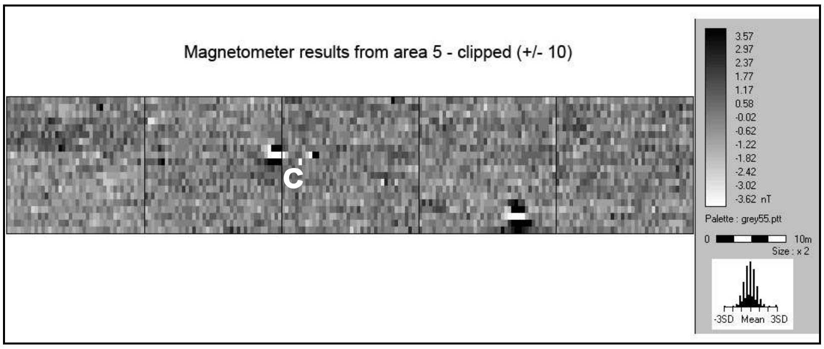

Figure 8 : Results for geophysical survey in Area 5

The results from Area Five show two significant dipole anomalies which are suggestive of burnt structures. Both anomalies are similar in form but the anomaly which spans the boundary of the second and third grid is notably higher than that in the lower sector of the fourth grid.

Geochemical Survey

Area One

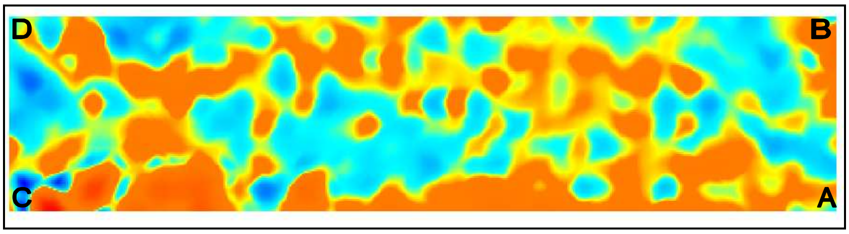

Figure 9 Spatial distribution of copper at Area One

Area One extends along the northern flank of Ecton Hill from Stone Quarry mine up towards the boundary wall. The area comprised four grids each measuring 20mx20m. Geochemical survey was undertaken at 2m sample intervals with a total of 400 analyses undertaken for the area. Readings ranged 6486ppm to no copper detected. Only 2% of readings were above 1000pm with 75% of reading being below 400ppm.

The highest concentration of copper is located on the edge of the first grid. No clear anomalies or concentrations are evident from the geochemical survey which correlate with geophysical anomalies.

Area Two

Area two was located on the sloping ground to the north-east of the area known as 'The Lumb'. This area is a good candidate for prehistoric mining activity. A total of six 20x20m girds were surveyed giving a total area of 60mx40m. Area Two included part of the area subjected to magnetometry survey by the EH team in 1998 (Bray and Horsley 1998) and resurveyed as part of this project. This area was also previously geochemically surveyed in 1998 (Doonan1998-see Figure 10 below).

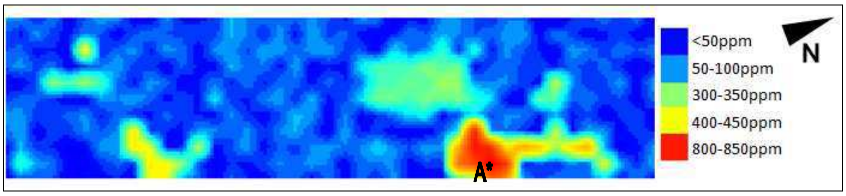

Figure 10. Previous geochemical survey undertaken in 1998 (taken from Doonan 1998)

There was a direct correlation between the EH geophysical survey and the geochemical survey undertaken in 1998 and indeed this correlation is repeated in the new surveys presented here. The location of Area Two was chosen to centre on the geochemical and geophysical anomalies which were clipped by the 1998 surveys. It is apparent that the anomaly is still present and this latest campaign of survey has served to better delimit its extent. Anomaly A* in Figure 10 corresponds to the spatial coordinates of **A'** in Figure 11 (c.f Figure 4 for geophysical results above).

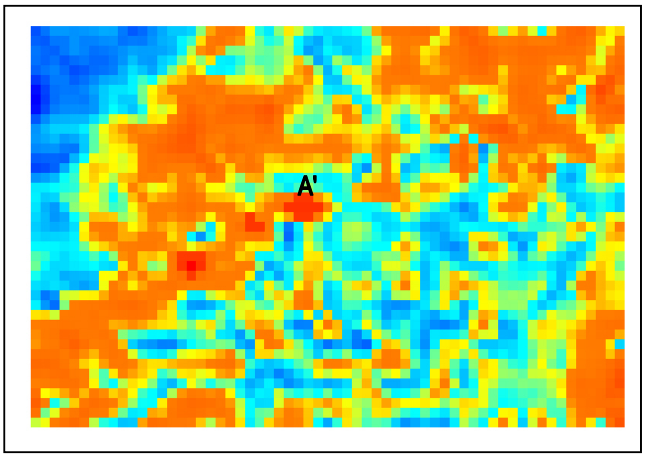

Figure 11. 2008 Geochemical survey at Area Two (copper distribution)

Again, geochemical survey was undertaken at 2m sample intervals with a total of 600 analyses undertaken for the area. Readings ranged from 18477ppm (a single high) to no copper detected. Only 1% of readings ranged between 800-1000ppm with 99% of readings being between 100-800ppm. There was good agreement between this range and that of the 1998 survey.

The most obvious copper anomaly is that highlighted as **A'** which seems to be in agreement with the geophysical anomaly identified in this area and with those identified in the 1998 surveys. There is a notable scatter of copper concentrations which stands in stark contrast to the results from Area Three (see below). The correlation between geochemical survey and magnetometry make this anomaly a potential candidate for further investigation.

Area Three

Area Three is adjacent to Area Two and is located on the sloping ground to the south-west of the area known as 'The Lumb'. A total of six 20x20m grids were surveyed (NB. eight for magnetometry) giving a 'L' shaped grid. No survey was undertaken by EH in this area in 1998. The geochemical plot of copper distribution should be compared with results from magnetometry shown in Figure 6 above.

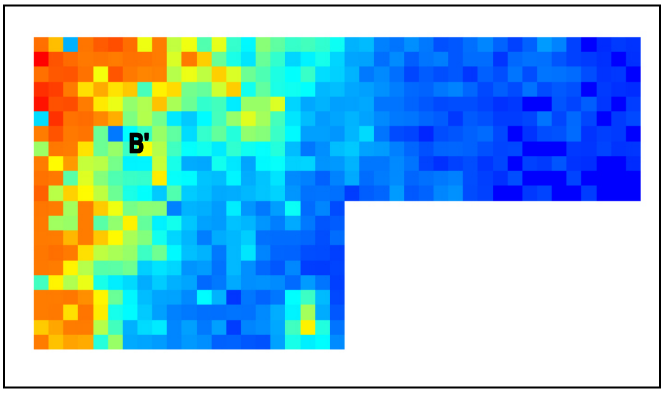

Figure 12. Spatial distribution of copper in Area Three

Again, geochemical survey was undertaken at 2m sample intervals with a total of 600 analyses undertaken for the area. Readings ranged from 6573ppm to no copper detected. Approximately 4% of readings ranged between 6000-1000ppm with 75% of readings being between 100-900ppm. The survey is notable for the relatively low copper determinations made away from the zone associated with mining (c.f. Area Two where copper concentrations remain high even at distance from the mining zone). The presence of generally high copper concentrations in area 'A' and the association of a magnetic anomaly in this area again suggest that there is the potential here for further investigation.

Area Four

The grid in Area four extends south-eastwards from the brow of Ecton hill over level ground away from the trig point. A total of four grids were surveyed amounting to a total area of 80mx20m. No survey was undertaken by EH in this area in 1998. The geochemical plot of copper distribution should be compared with results from magnetometry shown in Figure 7 above. Due to low copper concentrations being detected during random transects prior to systematic survey, geochemical survey was undertaken at 5m sample intervals with a total of 64 analyses undertaken for the area. Readings ranged from 157ppm to no copper detected. Approximately 50% of readings were below 100ppm. The survey is notable for the relatively low copper determinations across the survey area with the highest being towards the brow of the hill. This low concentration stands in stark contrast to the high levels detected in Areas Two and Three. Despite weak magnetic anomalies being detected by magnetometry the low concentration of copper suggests that this area has little potential for further investigation.

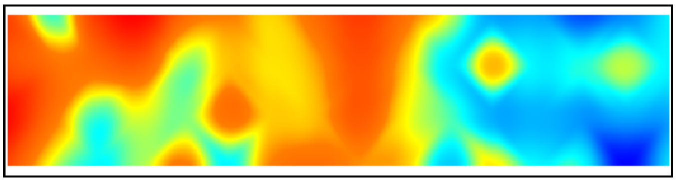

Figure 13. Spatial distribution of copper at Area Four

Area Five

The grid in Area Five extends approximately N-S immediately below Fly mine. A total of five 20x20m grids were surveyed providing a total survey area of 100mx20m. The results below (Figure 14) should be compared with the results of magnetometry shown in Figure 8. Due to low copper concentrations being detected during random transects over grids 2-5 prior to systematic survey, geochemical survey was undertaken at 5m sample intervals with a total of 64 analyses undertaken for grids 2-5 and at 2m intervals for grid 1. Readings ranged from 746ppm to no copper detected. Approximately 50% of readings were below 300ppm. The survey reveals no particular structure but does contain a copper anomaly **C'** (peak 746ppm) which correlates with a dipole anomaly identified through magnetometry survey. The presence of a dipole anomaly coupled with a high copper concentration suggests the potential for further investigation.

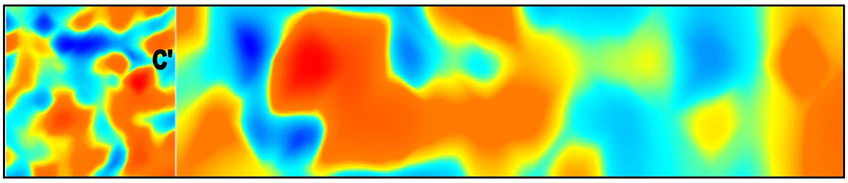

Figure 14. Spatial distribution of copper at Area Five

Conclusions

The combination of magnetometer (Figure 15) and geochemical survey (Figure 16) has allowed the identification of magnetic dipole anomalies associated with elevated copper levels in the soil matrix. Whilst there is no certainty that such evidence indicates the presence of ancient copper smelting remains the potential of these sites to yield such evidence can be considered high.

The locations of the proposed trenches (Figure 17) were selected on the following criteria

- Presence of a magnetic dipole anomaly
- Presence of elevated copper levels in soil matrix

Based on these criteria it is proposed to open three trenches each measuring 5mx5m at the following locations (Figure 17)

Trench One

Located in survey Area Two. It is proposed that one 5mx5m trench is opened that is centred on the significant magnetic anomaly (**A**) shown in Figure 4 and identified as anomaly **A'** in the 2008 geochemical survey (Figure 11). This anomaly was associated with copper levels in the region of 1000ppm and was previously identified in the 1998 EH surveys. Standard excavation methods will be employed and guidelines provided by Natural England will be followed. It is anticipated that the depth of the excavation will not exceed 60cm. The trench will be bounded using appropriate livestock fencing.

Trench Two

Located in survey Area Three. It is proposed that one 5mx5m trench is opened that is centred on the significant magnetic anomaly **B** shown in Figure 6 and identified as anomaly **B'** in the 2008 geochemical survey (Figure 12). This anomaly was associated with copper levels in the region of 4000ppm. Standard excavation methods will be employed and guidelines provided by Natural England will be followed. It is anticipated that the depth of the excavation will not exceed 60cm. The trench will be bounded using appropriate livestock fencing.

Trench Three

Located in survey Area Five. It is proposed that one 5mx5m trench is opened that is centred on the significant magnetic anomaly **C** shown in Figure 8 and identified as anomaly **C'** in the 2008 geochemical survey (Figure 14). This anomaly was associated with copper levels in the region of 700ppm. Standard excavation methods will be employed and guidelines provided by Natural England will be followed. It is anticipated that the depth of the excavation will not exceed 60cm. The trench will be bounded using appropriate livestock fencing.

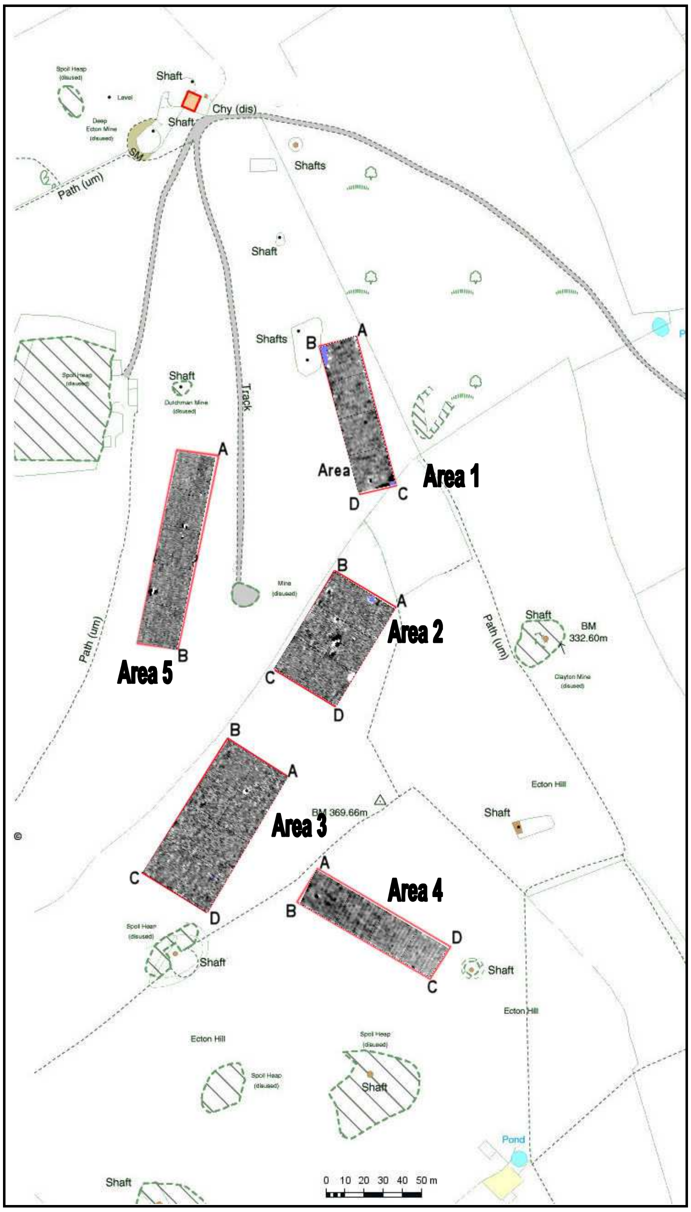

Figure 15. Map showing location of survey areas with geophysical data overlaid

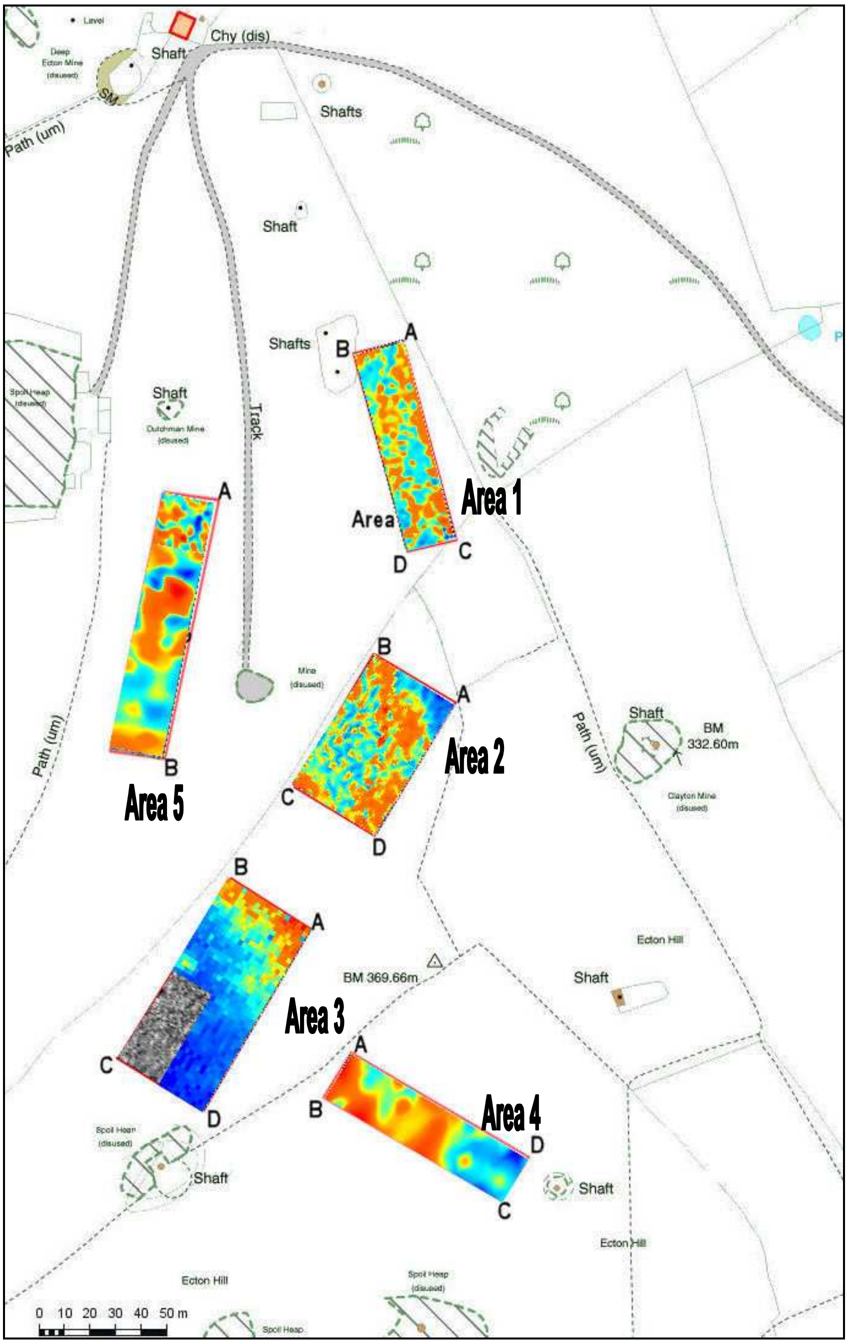

Figure 16. Map showing location of survey areas with geochemical results overlaid.

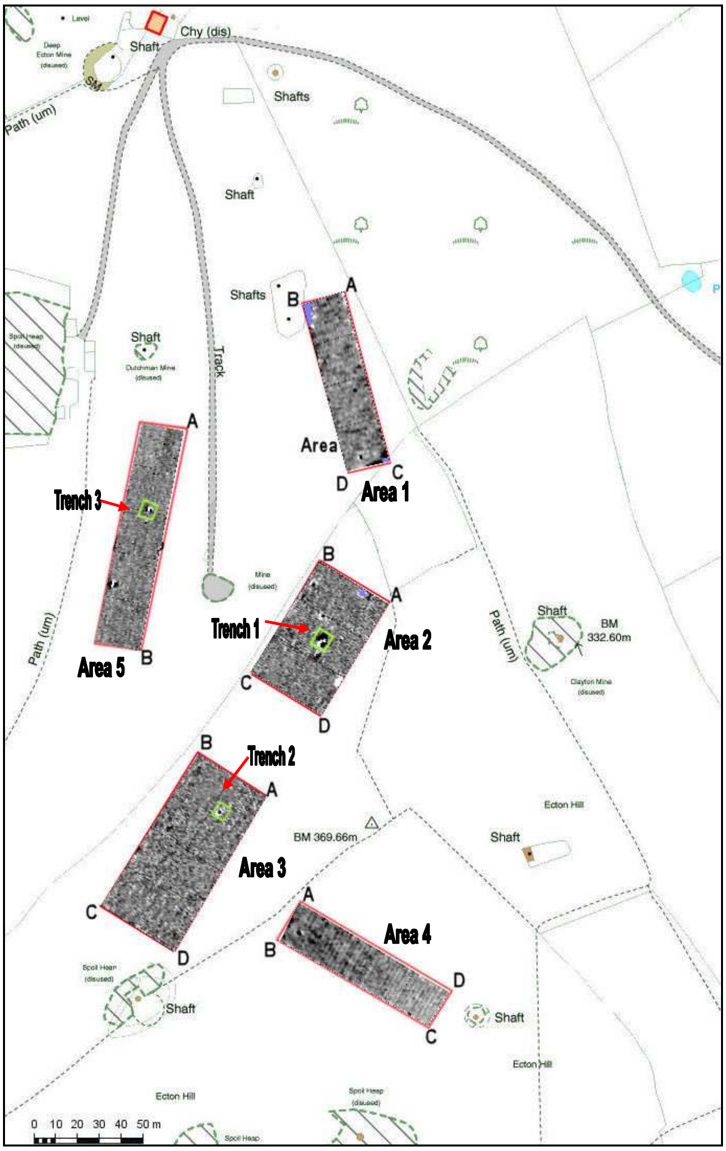

Figure 17. Map showing proposed locations of excavation trenches overlaying geophysical anomalies.

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APPENDIX

Analytical parameters for pXRF analysis

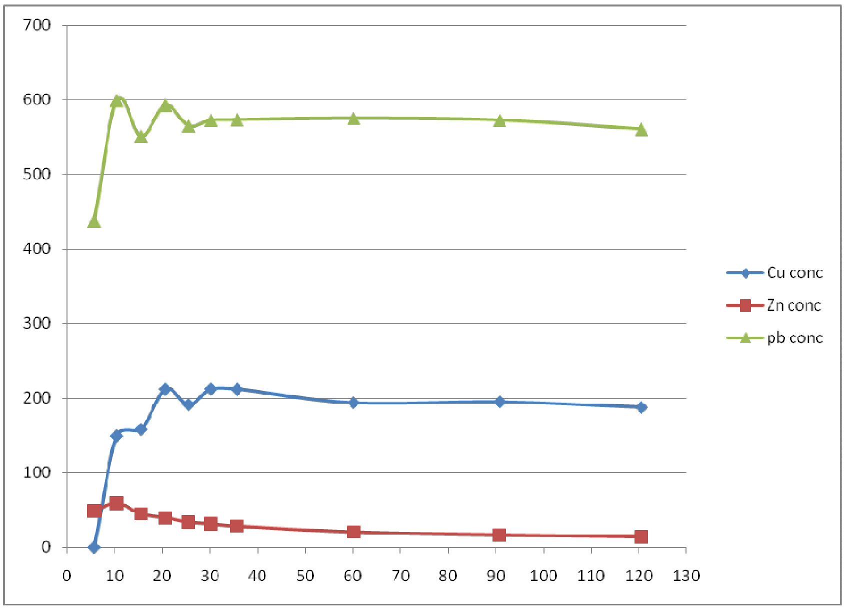


Figure A1: Analytical results for pXRF of random soil sample over time.

Figure A1 shows the results acheived for various analytical sampling times of a random soil sample. The data presented is for determinations of Cu, Pb and Zn. It is apparant that stable results are acheived after about 25secs for copper with similar results for Pb and Zn. Based on these results soil analyses were undertaken using an analysis time of 30seconds.

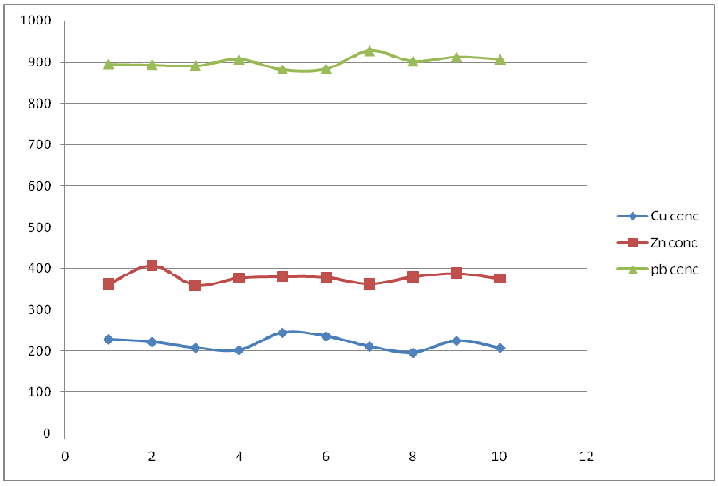


Figure A2: Graph showing replicate analyses of random soil sample with pXRF held in position

Analytical precision was determined by using the pXRF on a single soil sample and undertaking ten replicate analyses with the instrument secured in position.

The analytical precision was represented by the co-efficient of variation for Cu Zn and Pb and was determined as

Element	***CV %***
Cu	7.19478
Zn	3.767398
Pb	1.561647

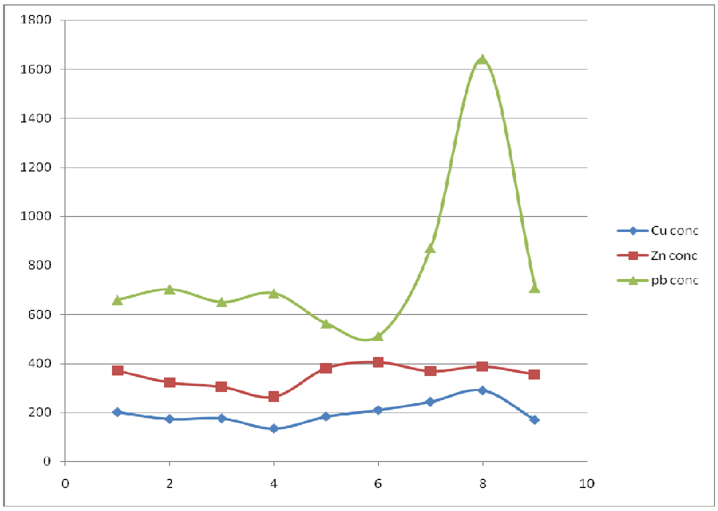


Figure A3: Graph showing replicate analyses of random soil sample with pXRF repositioned prior to each determination.

Method precision was determined by using the pXRF on a single soil sample and undertaking nine replicate analyses with the instrument removed from the sample and repositioned between each replicate determination.

The method precision was represented by the co-efficient of variation for Cu Zn and Pb and was determined as

Element	***CV %***
Cu	23.2973
Zn	12.98583
Pb	43.58298

The results for method precision can be compared to the CV for all results in a survey area (Area Two) where the variation amongst individual soil copper determinations can be seen to be 221%.

From these results and the variation encountered within the survey areas it can be asserted that variation identified in the field is due to variation in soil copper levels and not simply variation in method precision.

Summary

Subsequent to the geophysical investigations undertaken in May 2008, the survey area was extended to include the promontory to the north of the B&W Engine house (See Figure One).

Due to inclement weather conditions and scheduling difficulties the magnetometry survey is not yet complete, further survey of approx. 28 grids is required to finish the survey.

Despite the incomplete nature of the survey some features have been identified which warrant further investigation.

Methodology

A preliminary walk over survey was undertaken to evaluate any earthwork features which might be visible. Magnetometry survey was conducted using a grid of 20m squares. Gridsquares were laid out in advance of magnetometer survey and followed closely the line of the NW-SE running dry stone wall located to the west of the field (figure One). Temporary string lines were used to mark the data collection lines while the magnetometer data was been collected. The Geophysical surevey was undertaken using a Geoscan FM18 Fluxgate gradiometer and the data recovered was processed using GEOPLOT software. Further details of the instrument and processing are given in Appendix One.

The sampling interval was 25cm along traverses which ran NW-SE and were spaced 0.5m apart. This resulted in 3200 data points for each 20m square. A total of 32 squares (1.28 hectares) have been surveyed to date resulting in a total of 51,200 data points providing a pixel resolution of 0.25m.

The vegetation cover within the survey area ranged from thin to short grazed grass, with occasional concentrations of thorny shrub. Overall vegetation cover allowed the survey to be conducted easily. When survey was undertaken the weather was generally favourable although several campaigns were abandoned due to high winds. This means that the final results are the composite results from several days work. Whilst this may affect day-to-day precision of readings the results presented here so no significant weather effects.

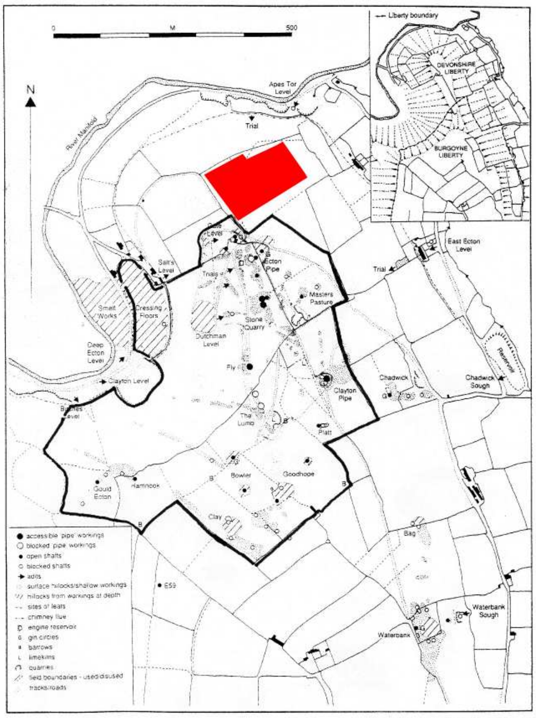


Figure One' Location of extended Geophysical survey (after Barnatt *et al* 1997)

Results

Running approximately north-south through the survey area is a prominent earthwork which is identified as a boundary (see Figure one). There is a defined terrace to the NE of the survey area.
The results obtained from magnetometry are shown as composite greyscale plots below. Results are shown as raw plots, interpreted plots and as satellite overlays.

It is apparent that several anomalies are evident; Dipoles, Linear features and Geological features.

Dipoles

Based on previous excavation of geophysical anomalies it is likely that these anomalies are caused by ferrous objects, although this cannot be absolutely certain.

Linear features

A faint but continuous linear feature runs north east along the edge of the survey are and then turns north west where it apparently splits and then returns to a SW direction. It is suspicious that this feature follows the line of the survey grid. It is possible that this anomaly might be the result of some form of edge effect. Upon completion of the survey this feature will be re-examined.

Geological features

These are labelled on figure three and five. They run approx. N-S and were noted as following the apparent bedding of the underlying rock.

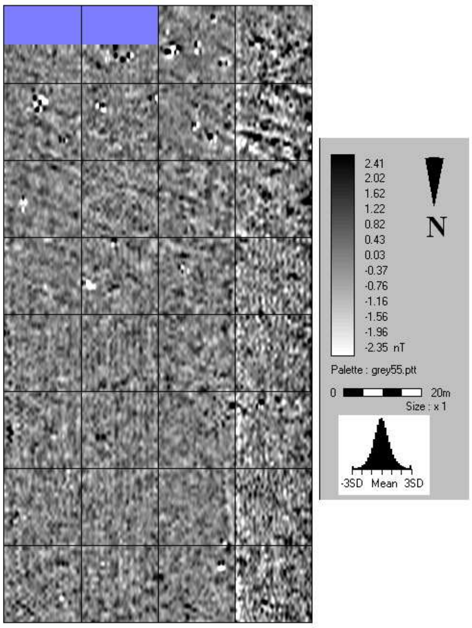


Figure Two: Raw plot of magnetometry data (NB Site North)

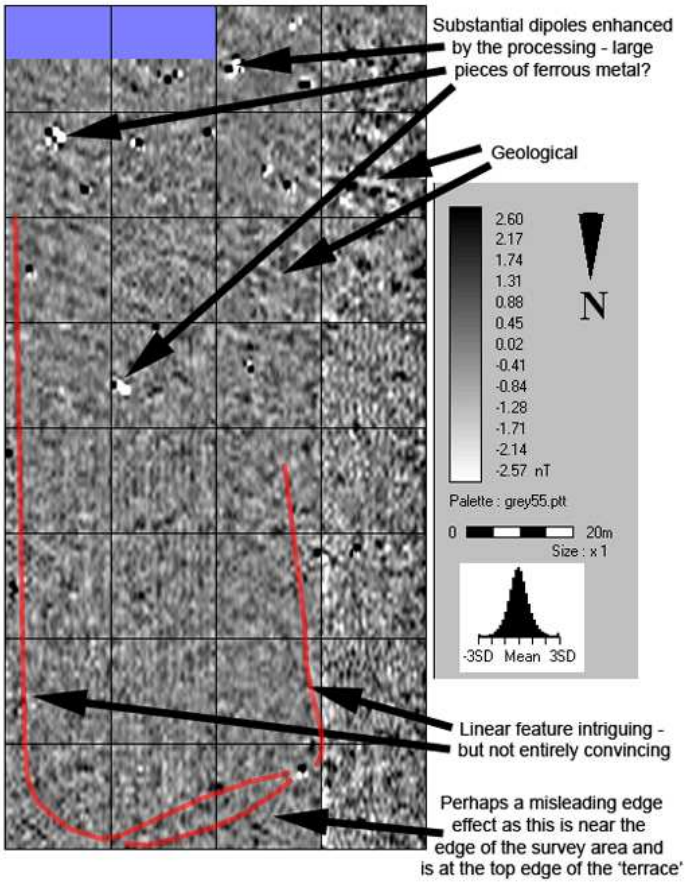


Figure Three: Interpretative plot of magnetometry data.(NB Site North)

Figure Four. Overlay of raw data from magnetometry on satellite image.

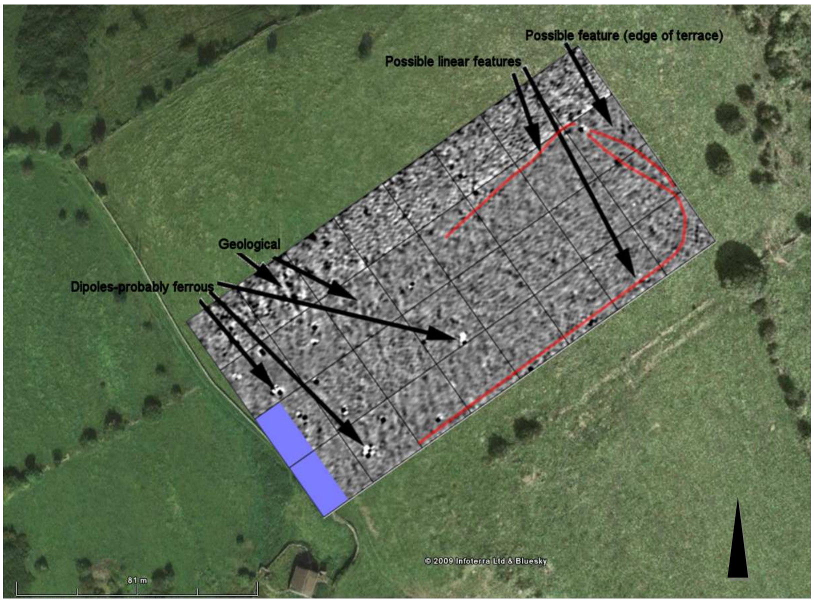


Figure Five. Overlay of interpretive plan on satellite image.

Conclusions

The results of the extended geophysical survey have identified some intriguing anomalies but the incomplete nature of the survey means that it is difficult to be conclusive about the potential of the site. Whilst it is likely that the dipole anomalies are caused by ferrous debris there remains the potential for these anomalies to be the result of in-situ burning. Limited geochemical survey will be able to establish whether there is any correlation with elevated heavy metal concentrations. Equally, these anomalies could be characterised by excavation. Each anomaly would require little more than a 1x1m test pit to resolve its origin.

At present the linear features are ill-defined and may equally be a processing artefact as opposed to an archaeological feature.

9.2. Excavation Report

PRELIMINARY ASSESSMENT REPORT
EXCAVATIONS AT ECTON HILL 2008

The University Of Sheffield.

Dr. Roger Doonan,
Ryan Eldridge
May 2010

1 Summary

Ecton Hill is located on the Derbyshire/Staffordshire border [SK 099 581) and has been the focus of copper mineral exploitation for millennia (Barnatt and Thomas 1998). A significant part of the study area is a Scheduled Monument (SM28883) with SMC granted from English Heritage prior to the initiation of this work. The project builds on work already supported by the Peak District National Park Authority (PDNPA) and furthers work initiated in 1998 by English Heritage (Bray and Horsley 1998; Doonan 1998).

Evidence for Prehistoric mining at Ecton includes finds of stone hammers and an antler pick radiocarbon dated to 1880-1630 BC. To date, there has been no evidence for prehistoric copper metallurgy being practised at Ecton. Whilst evidence for prehistoric copper mining has now been recognised at a number of sites in the UK (Timberlake 2003), evidence for copper smelting has proven to be elusive. The unique geological conditions at Ecton coupled with the character of later exploitation suggested that Ecton had good potential for preserving evidence for earlier episodes of copper smelting in the vicinity of mining operations.

Excavation strategy was informed by the results of geochemical and geophysical surveys (Doonan 2008) which had been undertaken in the previous phase of the work programme. Whilst little evidence exists on the surface for copper production at Ecton, the presence of fragmentary evidence from other sites in the Britain Isles, namely, Ross Island (O'Brien 2005) and the Great Orme (Roberts 2003), suggests that copper production may have been carried out in the vicinity of mining locations. It is assumed that the smelting of copper minerals employed a technology which relied on elevated temperatures being achieved within small ceramic or stone built structures. Such pyrotechnical structures can be detected by magnetometry survey as discrete dipole features and can be expected to be associated with elevated copper levels in the soil matrix.

2 Introduction

This is the assessment report for the archaeological interventions carried out by Dr Roger Doonan, University of Sheffield, as part of the Ecton Hill project supported by English Heritage and carried out in cooperation with archaeologists from The Peak District National Park and The Early Mines Research Group. All fieldwork was done in accordance with the Project Design approved by English Heritage. This report mirrors standards and practices contained in the Institute of Field Archaeologists' *Standard and guidance for archaeological field evaluation* (IFA 2001a) and *Standard and guidance for the collection, documentation, conservation and research of archaeological materials* (IFA 2001b).

The work reported here was carried out between 1st -18th September 2008

3 Archaeological background

Ecton Hill is characterised by a palimpsest of earthworks across its NW face relating to episodes of mineral extraction and associated activities. Hammerstones presumed to be tools used for mineral extraction have been reported from both spoil heaps and underground workings (Guilbert 1994). More recent work (Barnatt and Thomas 1998) recovered an antler pick which for the first time allowed mining activities at Ecton to be securely dated to the Bronze Age.

The secure dating of mining activities to the Early Bronze Age confirms the potential for Ecton to produce evidence for associated copper production. A number of copper alloy finds have been recovered from the vicinity of the Ecton mines including what appears to be an EBA flat axe from Sycamore cave (Houdmont 1991) Whilst such finds cannot be considered evidence for primary metallurgy being practiced at Ecton the presence of such finds indicate the circulation of metalwork in the vicinity of Bronze Age mines.

4 Aim

The aim of the archaeological intervention was to establish and record the character of the archaeological remains, if any, that were producing the geophysical and geochemical anomalies detected in the surveys referred to above.
Ultimately it was anticipated that when geochemical and geophysical anomalies overlaid one another there was a high potential for locating a copper production site.

5 Results

Excavations at Ecton in the 2008 season comprised of two trenches (1 and 2) each measuring 5m x 5m(Figure One).

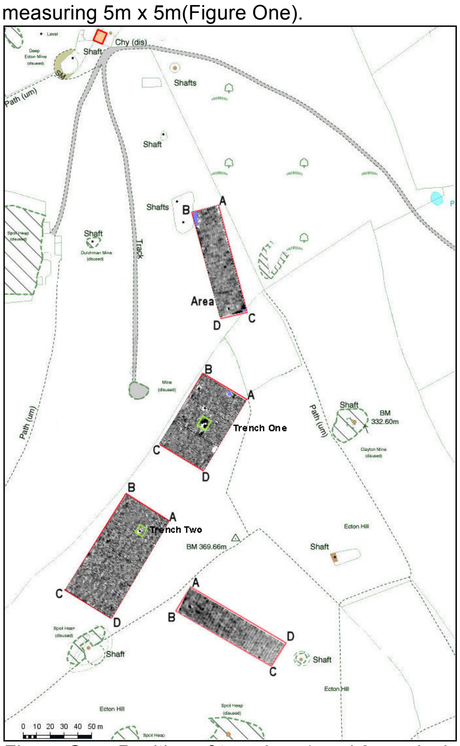


Figure One: Position of trenches 1 and 2 overlaying geophysical anomalies.

Trenches were excavated by staff and students from the University of Sheffield under the archaeological supervision of R. Doonan. Hand tools were used for all excavation with turf being removed by hand with all sods stacked in the manner prescribed by Natural England.

Both trenches were positioned so that the anomalies identified from survey were centrally positioned within the trench. Trench one incorporated a trackway which ran N-S along the flank of the hill. Trench two incorporated no visible earthworks.

5.1 Trench One

Trench One was deturfed by hand using spades. Once deturfed (Figure Two) a single soil horizon with a spread of gravel in the vicinity of the trackway was revealed.

Figure Two: T1 prior to deturfing

Subsequent cleaning by trowel exposed a light brown loose soil which extended over the entire trench (Figure Three).

Figure Three: T1 with turf removed and cleaned.

Continued troweling in the central area of the trench exposed a significant ferrous object which upon further excavation was found to be a section of modern fencing rail (Figure Four).

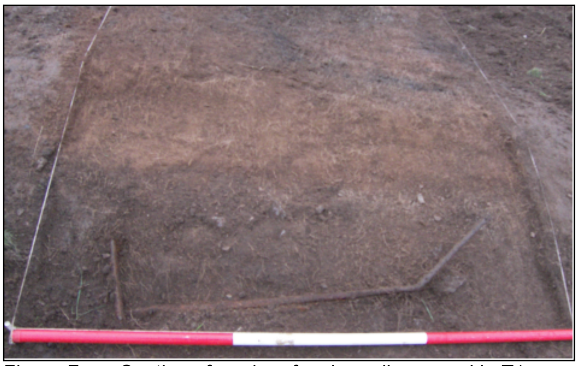
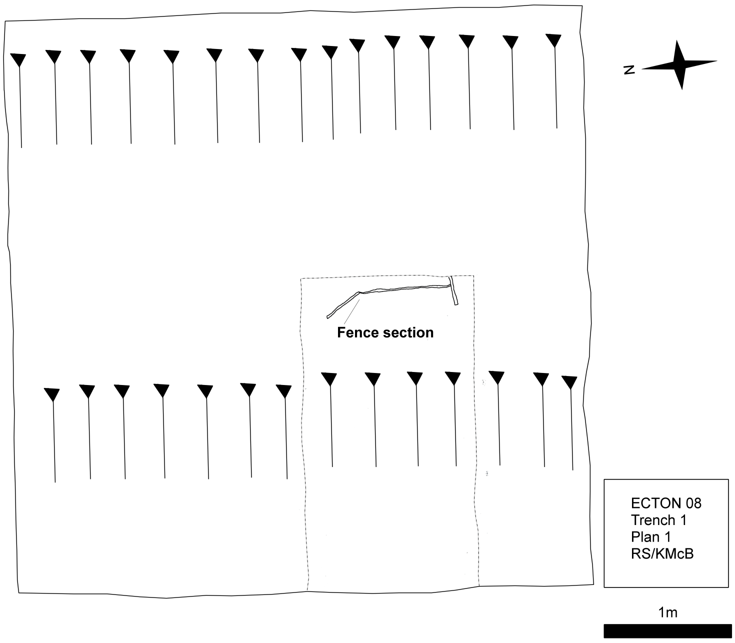


Figure Four: Section of modern fencing rail exposed in T1



No doubt this object was responsible for the magnetometry anomaly. Subsequent in situ geochemical analysis noted a copper anomaly in the vicinity of the ferrous object.

No other finds were made.

Following excavation, the trench was backfilled and the turf was repositioned in accordance to the method prescribed by Natural England.

5.1 Trench Two

Trench Two (Figure Five) uncovered a scatter of limestone block tumble sitting on a red brown soil. A single feature was noted in the centre of the trench which corresponded with the position of the anomalies noted in the survey (Figure Six).

Figure Five: T2 in the process of being deturfed.

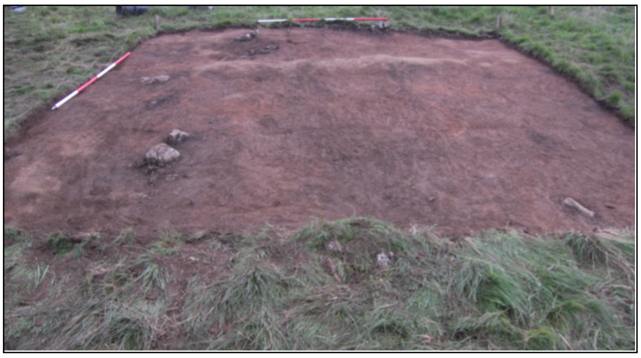


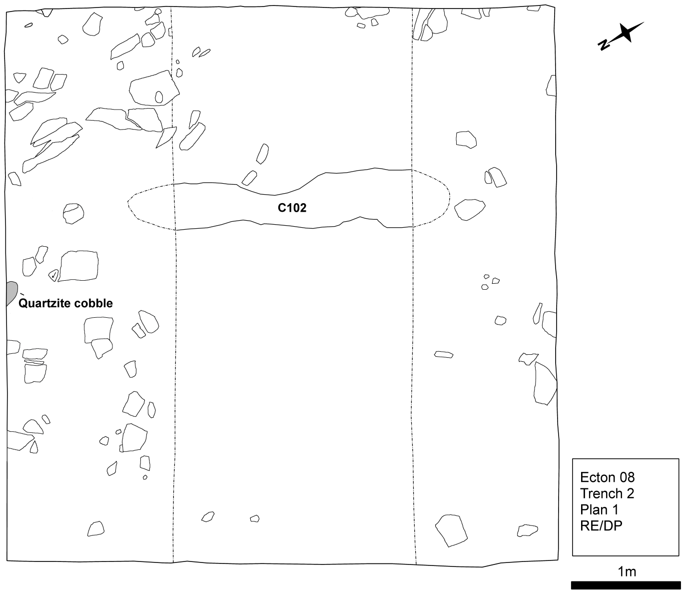
Figure Six: Turf removed with 'feature' revealed as drying line (lighter area)

The feature comprised a poorly developed platform which resembled a sheep scar. It was approximately 3m long and 60cm at its widest. A number of small rock fragments were noted in the soil matrix during cleaning including a number of mineralised fragments. Neither these fragments nor the feature exhibited any characteristics which suggested that it was anything but natural.

Sectioning of the feature failed to identify any distinct horizon between the ‘feature’ and the red brown soil which characterised the rest of the trench. The differential drying of the feature was thought to be more related to topographic variation than context.

Subsequent geochemical analysis noted elevated copper levels in the ‘feature’ especially in the vicinity of mineralised rock fragments. No finds were made which could easily explain the anomaly identified by magnetometry.

A single Quartzite cobble was recovered near to the surface on the NE side of the trench (See Timberlake-this archive).



Following excavation, the trench was backfilled and the turf was repositioned in accordance to the method prescribed by Natural England.

6 Finds

There were no significant archaeological finds. The modern fencing rail was deposited at the field boundary. The Quartzite cobble showed no evidence of wear or modification but was, nonetheless, submitted to the EMRG for further study and drawing.

7 Discussion

Despite the potential for copper smelting activity to be present at Ecton it is apparent that the anomalies investigated in the 2008 season did not produce evidence to confirm the presence of copper metallurgy on Ecton Hill.

Whilst it is anticipated that evidence for copper smelting may well be ephemeral (Craddock1995) it is not unreasonable to expect the survey methods employed to be effective for locating such activities (Doonan et al in press; Behar et al 2008). The areas surveyed were considered to be the most likely areas for copper smelting activities to be located within the study area yet other likely candidates within the vicinity of Ecton Hill exist.

Despite the results of excavation producing what might be considered negative results it is worthwhile recognising the significance of these results. Smelting sites on the continent have not been difficult to locate with many such sites being reported in the literature (Craddock 1995). Indeed , it seems that wherever copper mining has been located on the continent copper smelting has been found accompanying such activities. This is not to say that such activities are always located in the immediate vicinity of mining activities but that the do appear to be at least visible. The contrast with Britain is significant and whilst the results from this study do not convincingly demonstrate that smelting is or isn't present on Ecton Hill there is at least now a weight of evidence which indicates that smelting was most likely not undertaken in the immediate vicinity of prehistoric mining sites. The reasons for this are no doubt manifold and may relate as much to functional concerns such as the availability of resources as they do to appropriate understandings of space. The outcome of this study does at least indicate areas which are potential sites for further study on Ecton Hill whilst also highlighting the need to project future studies further afield than the immediate surroundings of mining sites.

8 Archive deposition

No finds were retained.
The paper and digital archive is currently held by The Peak District National Park with a permanent deposition being made in line with standard procedures.

9 Acknowledgements

This aspect of the Ecton Hill project would not have been possible without the cooperation of the many landowners who facilitated the survey and excavations. Special thanks are owed to Tommy Allen and Bill Mellor along with Henry Rusch and family.
Thanks are also owed to the team of EH inspectors who oversaw the project. Finally, special thanks to John Barnatt, Senior Archaeologist with PDNP, whose initial efforts and ongoing management made the whole project possible.

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