ENVIRONMENT, ANTECEDENT AND ADVENTURE: TIN AND COPPER MINING ON DARTMOOR, DEVON, *c.*1700-1914

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by

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ABSTRACT

The tin and copper industries of Dartmoor in Devonshire are investigated through an analysis of the earthworks and ruined structures which constitute the surface evidence of mining. An entirely new body of data has been assembled resulting from field investigation, survey and documentary research, focussing specifically on the surface remains of underground mining, the dressing of the ores and the evidence for water power. This has enabled a reconstruction of key elements of the mining landscape and established the scale of the processes involved.

An analytical methodology has been developed which contextualises the archaeological remains in terms of local environment and social antecedent, together with a broader framework of inference based on consumption, global trade in metals and the impact of historical capitalism on the organization of mining. This has provided a novel interpretive framework that combines the environmental and social inimitability of a mining region with contemporary global, socio-economic trends. This precise approach has not previously been applied to any mining district in the United Kingdom.

The results demonstrate that for the study period *c.*1700 to 1914, Dartmoor shares many historical and technological similarities with other mining districts in the south-west peninsula. However, its environmental configuration of marginal ore sources and plentiful water supplies, together with a strong belief in the resources by those who strove to exploit them, following centuries of tradition, enabled an industry to survive, albeit materially small in scale, over much of the late 18th and the 19th centuries. The dynamic role of capital investment through joint adventure is also examined in the light of these considerations and the results suggest that on Dartmoor at least, the genesis and impact of capitalism had a character partly determined by locality.

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My biggest debt of all is to my wife Lynne who has tolerated my incapacity to contemplate anything other than the content of this thesis for far too long, but who has shared the emotional burden during the inevitable and frequent crises that have formed part of the process.

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INTRODUCTION

The upland of Dartmoor in Devonshire and its surrounding border country, has been at the forefront of archaeological research in western Britain for over two centuries and is familiar to archaeologists for its well-preserved and highly visible prehistoric archaeological remains (Fleming 2009). Despite the indisputable richness of the evidence for prehistoric episodes of activity on and around the moor, it is the remains of past extractive industries from the medieval period and later, which are arguably the most pervasive and visually striking elements of human intervention in this landscape, where metal mining was taking place between at least the 12th and the 20th centuries with only minor interruptions to its continuity. Notwithstanding its archaeological and historical potential, the significance of Dartmoor as a mining district has also frequently been overlooked in studies of Westcountry (i.e. Devon and Cornwall) mining, which are dominated by the work of Cornish historians (e.g. Buckley 2005, Barton 1961; 1967, Penhallurick 1986). This thesis seeks to rectify this through an investigation of mining remains on Dartmoor, which is, for the benefit of this study, considered to be one of several metalliferous mining districts within the south-west peninsula that merit archaeological and historical investigation (others being Bodmin Moor, Tamar Valley, St Just, Camborne, St Austell).

The study follows a multi-scalar contextual methodology whereby the field evidence is assessed within the contexts of the local environment, social antecedent, consumption of materials and the impact of historical capitalism. It focuses specifically on the mining of tin and copper but includes aspects of silver-lead between *c.*1700 and 1914. The beginning of the 18th century is a convenient chronological point for an investigation to commence, situated within a hiatus of activity between the demise of the post-medieval tin industry in the late 17th century but before the advent of modern mining for tin and copper. Although both industries were moribund on Dartmoor before 1914, the start of the Great War, when many miners were sent to the front, represents the end of a viable industry in this district.

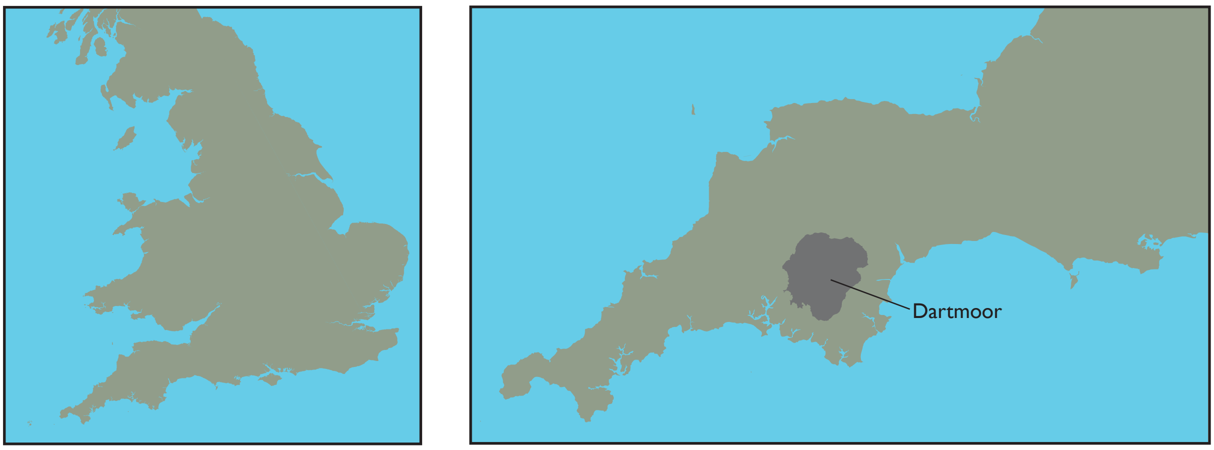


Fig One. Location map of Dartmoor. See also Fig 6.1.

Methodology and Aims

The potential for new insight on this topic is immense. Firstly, no previous archaeological investigation into the Dartmoor mining industry for this period, incorporating fieldwork on such a scale, has ever been undertaken in this district. Second, the archaeological resource itself is particularly impressive; 435 mining enterprises promoted during this period have been noted from historical documents within the study area, though this is not yet exhaustive, and field evidence has been recorded at over 104 locations to make up the sample for this research. This programme of fieldwork and its resulting body of data has the potential to supply entirely fresh insights and enable new interpretations concerning the mining elements of the Dartmoor landscape and contribute to broader discussions of British mining during the 18th to 20th centuries.

The analytical approach (Chapter 2) combines the results of archaeological field investigation with historical context, within a predefined framework of inference (Chapter 1). This contrasts with previous studies on this theme, which on Devon's uplands have been examined mostly through documentary sources alone (Barton 1961; 1967, Hamilton Jenkin 1974; 1981). Where fieldwork has taken place in the past, effort has been directed at standing buildings, machinery, technology and processes (Booker 1974; Harris 1968), or discussions of individual mine sites (Greeves 1975; 1976; 1978; Bird & Hirst 1996; Newman 1999; 2003). These are important contributions towards an understanding of mining and similar material will form part of this enquiry but in the past, analysis has often fallen short of what is required to illuminate the place of mining and its products within contemporary societies, or examine how the demands and culture of those societies shaped the way miners and mine adventurers conducted their work.

The research embraces several new lines of enquiry but begins by tackling some basic issues as a means of assembling a useful body of data. Where were the mines? How extensive are the remains and how well preserved? What can the field remains tell us about the size and duration of individual operations, and the technology that was used, including sources of power, ore dressing, pumping and hoisting machinery. To what extent may documents complement the field evidence by providing context for the behaviours of those involved in the industry?

Having collated this evidence, the investigation moves to more complex issues and examines the choices made by those involved as to how they could best develop their industry within the social, economic and environmental contexts of the time and place. Was behaviour and the organization of mines influenced by antecedents in the form of tradition, ancient practice and the landscape legacy of earlier miners? How did the particularities of the local environment and natural resources shape the nature of the industry here and was mining always undertaken on the basis of sound geological knowledge and a solid grasp of commerce? What part did technology play in the progress of the industry in this district and how might the rapidly increasing consumption of the metals have influenced the development of the Dartmoor industry? Finally, what was the role of capitalism in providing the broader dynamics of economy and a social context for change in the mining industry within the study period; what form did capitalism take and how did it develop and influence the trajectory and nature of specific changes to mining within the study area?

The large volume of documentation and high density and variety of field evidence that this study has the potential to embrace, requires that fieldwork has had to be limited to the surface evidence of extraction and processing of tin and copper ores. Other elements of the mining industry including transport, smelting, underground archaeology and social infrastructure such as housing and settlement, as well as a more thorough examination of the contemporary landscape, would further expand this topic but space dictates that their contribution will need to be considered elsewhere.

Fieldwork methodology

For data-gathering this study utilises the well-established technique of archaeological field investigation, practised in this case at a variety of levels and explained in detail in Chapter 2. Exploring elements of past landscapes through reconnaissance, observation and survey of earthworks and ruined buildings, is one of the oldest techniques available to the archaeologist but remains the most effective and low-cost means of analysing the visible evidence of individual sites or entire landscapes. Although a long-standing technique, field investigation has benefited from the input of modern technology such as electronic survey instruments including the 'total station theodolite', global positioning systems (GPS) and computer software such as computer aided drafting (CAD). As a result recording is more rapid and presentation of results is more flexible. All of these advances have played a part in this study, however it is the skill and experience of the practitioner, which is the key to the effectiveness of this technique.

The author is the beneficiary of a long tradition of field investigation and survey, having been trained by members of the former Ordnance Survey Archaeology Division and the Royal Commission on the Historical Monuments of England (RCHME) Investigation Team in the early 1990s, followed by 18 years of professional experience investigating a diversity of landscapes and archaeological sites in England. It is within the context of this professional work that a long-standing research interest in mining archaeology was further aroused when assignments included analytical surveys of mines within Dartmoor National Park. For the majority of these mines, little or nothing in terms of field recording or interpretation had previously been undertaken. It soon became clear that a more complete study was needed, focussing on a defined period, establishing the extent of the field evidence, recording it where possible and analysing the data within a predefined research context. Equipped with the necessary skills, resources and opportunity, the author was uniquely placed to undertake this programme of research.

Structure of the thesis

A discussion of the research context, in which the work of previous writers is collated and an appropriate theoretical approach established (Chapter 1), is followed by an explication of the methodology used to carry out the field research (Chapter 2). The contexts for the south-west England mining industry are then explored; the local environment is examined first, covering the geology of the district. At a more global level the demand, consumption and economics of the metals, and how these issues would have influenced the mining activity on Dartmoor are considered (Chapter 3). The latter theme is continued with the historical aspects of the Dartmoor tin and copper industries presented in Chapter 4, which includes a discussion of the period leading up to the commencement of the study (i.e.1700) and focuses particularly on commentaries from contemporary writers but includes primary sources specific to individual mines. The impact of capitalism and the unique trajectory of its development within the traditions of Westcountry mining are examined in Chapter 5 together with mine organization and the business of promotion and investment. Field archaeology is covered in Chapters 7 for extraction, 8 for ore dressing and 9 covers water power. Illustrations of key sites based on surveys carried out by the author are included in Chapters 7 to 9. The data are presented thematically drawing examples from a database that is the product of detailed fieldwork; some aspects of the data are presented in tables within relevant chapters, although the bulk of the historical data is in the form of an appendix. The results of the research and conclusions (Chapter 10) integrate the contexts and data in a summarizing discussion. Finally, an outline of future research priorities for this topic arising from the results of this work, and suggestions as to how further work might progress, are provided.

CHAPTER ONE
RESEARCH CONTEXT

1.1 A REVIEW of METHODOLOGICAL and THEORETICAL APPROACHES, THEMES and POTENTIALS

Summary

When referring to the ‘diversity of approaches’ now practised in the study of past mining for metals, Bernard Knapp stated that as a topic it is ‘the bailiwick of several different disciplines’ (Knapp 1998, 1). This is indeed so on the international academic scene to which Knapp alluded but in the south-west of England, accounts of past mining have traditionally been the domain of historians, and the control of the narrative has been firmly in the hands of writers whose main concern was the Cornish mining industry (see *pp*15-17 below; Hamilton Jenkin 1974; 1981; Earl 1968; Barton 1961; 1968; 1970; Buckley 2006). This thesis aims to address this somewhat slanted perspective, firstly by presenting a balance of historical and archaeological evidence but also by moving the focus onto the mines of Devon, Cornwall’s neighbour, bringing fresh data to the discussion.

Archaeological research aimed specifically at mining has been undertaken on Dartmoor in the past and previous work is examined below, but this is the first major study to expose a large corpus of data to a theoretically derived ‘framework of inference’ to quote Palmer (2005, 59-76) and arrive at some meaningful conclusions. As the data are particularly numerous and specialised, it has been necessary to develop an eclectic approach to data analysis; in the following review industrial, landscape and historical archaeological approaches are considered in the light of contributions by previous researchers who have explored this and closely allied topics. Each methodology is discussed in the context of how they might individually or collectively support the analytical processes needed to elucidate the topic of mining archaeology in rural uplands such as Dartmoor. This is followed by a statement explaining the theoretical choices made in the analysis of the data.

1.1.1 Industrial Archaeology

Industrial archaeologists have focussed on the material evidence of industrialization through the themes of production, distribution and consumption (Symonds & Casella 2006, 149). But in the first decade of the 21^{st} century this discipline’s main debate has stemmed from criticism that traditional industrial archaeology has focussed too heavily on function, form, chronology and monumentality whilst ignoring other levels of meaning and the need for a theoretical research paradigm (Symonds 2005, 33-57; Gwyn 2005, 129; Palmer 2005, 59-75). This debate has broadened through a number of publications (Palmer & Neaverson 1998; Casella & Symonds 2005; Gwyn & Palmer 2005; Barker & Cranstone 2004; Horning & Palmer 2009) in which numerous authors have set out ideas on realigning the scope of industrial archaeology, with many claiming the need to work within a social and political agenda as well as the 'experience of the workplace' (Symonds 2005, 46) whilst diminishing the importance of the role of machines and technology (Gwyn 2005, 129). As a concept this is not universally accepted and a counter view supporting a more traditional research paradigm has been raised by Holden, who maintained that:

> *An understanding of technology must remain central to the task of understanding industrial buildings.*
>
> (Holden 2009, 261)

Within this more traditional school of opinion, 'theorization that fails to engage with technology by hiding behind social-science jargon' (Nevell 2009, 32) should be rejected. Certainly, for this thesis a more inclusive path will need to be found through these conflicting ideas if the methodological and philosophical basis of industrial archaeology is to have anything to contribute. Although it is agreed that the trend for re-focussing onto socially-driven research has great merit, caution is needed before embracing a rigid adherence to a specifically 'workplace' or 'social' agenda, which constrains the potential of industrial evidence and technological change to address other equally intriguing questions about human behaviour and society in the past. A middle way would be to consider the social dimension as a complementary line of discussion, which provides additional context to the impact of technology.

Beyond the ongoing discussions on the scope and intellectual direction of industrial archaeology, few from within this discipline have focussed their research on the spatially fragmented, discrete, upland, rural landscapes of small metal mines such as Dartmoor. Even fewer have considered the importance of earthworks and heavily ruined structures within the more progressive research context currently espoused; there are exceptions however. Palmer and Neaverson's comparative study of tin and lead dressing sites is an early example of a problem-oriented examination of field and excavated evidence supported by documentary research, which was an attempt to redress the imbalance of conclusions derived solely from historical sources. Many of the issues and problems involved in the handling of certain forms of data discussed in their paper are similar to those addressed by this thesis (Palmer & Neaverson 1989, 20-39). Most significantly, their work attempted to examine technological development in its human context; something both technologically- and socio-theoretically-minded industrial archaeologists might relate to.

Despite such exceptions, the techniques of modern industrial archaeology and consequentially much of the debate within that discipline, have mainly been applied to urban built environments, a point acknowledged by Palmer, who stated that 'In Britain, much of the evidence for the industrial period is provided by standing buildings' (Palmer 2005, 61). For those studying the built environment, the function of intact or near intact buildings is often self-evident, allowing the archaeologist in search of other levels of meaning a head start over those concerned with earthworks, who first have to establish function by recording then deciphering or unravelling the various elements. This has been one of the primary tasks required in the compilation of data for this thesis and is precisely why the investigative approach is so suitable as a methodology in the study of rural mining; when supported by relevant documentation it enables an informed reconstructive element to precede and be incorporated into the interpretation (see Chapter 2).

1.1.2 Industrial Landscapes

In the past some authors have presented investigations of extractive industries of similar character to that of Dartmoor as 'landscape archaeology' with various degrees of success; given the high level of landscape data that this thesis deals with, such techniques require major consideration. Bowden noted that the application of investigative techniques to industrial landscapes generally is a relatively recent phenomenon (Bowden 1999, 139) and Britain's major specialist journal, *Landscape History,* has only very recently begun to embrace the topic of mining (Faull 2008; Hughes 2008) following over 27 years of publication during which only a handful of papers appeared (Lowe & Lawler 1980; Palmer 2000; Gwyn 2001; Whyte 2004, 111-21). Elsewhere, Roe has written on aspects of landscapes associated with lead mines (Roe 2007, 9-22) including the important concept of 'hidden' underground landscapes. Cranstone also touched briefly on mining landscapes, although focussed very narrowly on the 'impact' of industrial features rather than seeing them as part of more a holistic landscape approach (Cranstone 2001, 201). The contribution of Jones et al (2004) and Bowden (2000) are considered below.

Landscape archaeology as a concept is open to differing levels of meaning depending on the heuristic principles and stated aims of those who study it. Ashmore and Knapp for example, when explaining the development of a 'cultural' approach claim:

> *..the most prominent notions of landscape emphasise its socio-symbolic dimension: landscape is an entity that exists by virtue of it being perceived, experienced and contextualised by people*
> (Ashmore & Knapp 1999, 1)

For this 'school' one objective is to gain insight as to how people of the past perceived their surroundings and to reveal meanings which exist in features of the landscape as a result of human expression, ideology or social interaction.

Although it is a challenge to perceive 18th to 20th-century extractive landscapes in terms of human expression, as they are unlikely to be designed landscapes, mining features owe their existence to the material demands needed for a society to express itself and do contain some designed elements resulting from human choices which can be identified. However, most examples of the human expression which resulted from extractive landscapes will be found far away from the mineral sources in the products, buildings and artefacts fashioned from the materials. Where the cultural approach is more relevant is in the concept of experiencing the landscape through the accumulated material evidence of what has occurred within it in the past. Ingold has made the point that if archaeologists equipped with the necessary specialist skills are able to recognise and interpret the significance of clues to the past within the landscape, so too would various specialists in the past (Ingold 1993, 153). He uses the example of hunters but it could be applied to mineral explorers; any person who was mineralogically aware would be able to recognize the mining activities of those who had previously exploited the resources and would know how to act upon what they were witnessing for their own benefit. This is certainly a useful concept when attempting to understand the behaviour of 18th and 19th-century miners who were re-working older mines.

An alternative opinion is that 'A landscape is an environment that exists independently of those who live in it' and the aims of this approach are to 'explain patterns of social behaviour in terms of adaptation to the natural environment' (Layton & Ucko 1999, 1-2). This is the foundation of landscape archaeology as practised in Britain by scholars such as Everson and Williamson who stated that:

> *In essence, landscape archaeologists are concerned with explaining how what we see today came to look the way it does, and with interpreting the spatial patterns and structures created in the past in terms of social and economic behaviour.*
>
> (Everson & Williamson 1998, 1)

These aims were achieved by Rippon et al (2009) with their exploration of the medieval Bere Ferrers silver mines. This research brought together the archaeology of mineral extraction and its economic and social impact, manifest through infrastructure including woodland management, transport systems and the procurement of water; most significantly, through settlement patterns and contemporary agriculture.

For both approaches landscapes need to be perceived holistically, as in this example, with less emphasis placed on interpreting sites as entities and more on their context, environment and evidence of other human activities, contemporary or otherwise.

From the limited body of work on British extractive landscapes cited above, all follow the second philosophy. Palmer's 2000 paper discussed the methodology in some depth, outlining the processes to successfully study industrial remains within a landscape context:

- determine the reason for the location of particular industrial enterprises
- interpret the changes to them through time
- examine their spatial relationship with each other and with the development pattern of settlement and transport

Of these points number 3 is often overlooked. One specific attempt at this approach was the work of Jones et al (2004) with a survey of metal mining landscapes of mid and north-east Wales. In this example the authors claimed the 'emphasis is upon the landscape perspective' (Jones et al 2004, blurb).

However, although describing topography and interpreting the extractive archaeology of mining as landscape entities in preference to a micro, site-oriented style, this work does not place the individual mining sites within the broader context of their contemporary human landscape; the levels of meaning that Ashmore and Knapp (1999) may have been looking for in a landscape study, or the spatial analysis in terms of economic and social behavioural elements that Everson and Williams (1998) would expect are therefore lacking. The same statement could be made of Roe's 2007 paper, as this author similarly does not venture outside his comfort zone of the extractive evidence.

These examples highlight the difference between integrated and mono-thematic styles of landscape investigations, where in both cases the landscape concepts described above are not fully addressed. In Bowden's *Furness Iron* (Bowden 2000) a different approach was used. This too is a landscape investigation: it is an examination of the iron industry within a particular district but the author does not use the term 'landscape' unless describing context, including ore sources and other natural resources such as water power and fuel supplies. This more explicit usage closely defines the parameters of the term 'landscape' as intended in this thesis, where it refers to context not concept and although this is a landscape investigation, no claims are made for it being 'an archaeology of landscape'. But despite this choice, it is necessary to be alert to the fact that the miners themselves were often responding to their own experience of the landscape, its resources, its topography and its past.

1.1.3 Historical archaeology

Past extractive industry themes can be very usefully examined within the methodological and theoretical context propounded by historical archaeologists. For this thesis historical archaeology is understood to be, as defined by Hicks and Beaudry (2006, 2), the archaeological study of the period after AD1500 rather than any specific period for which historical evidence may survive. As a term, in a similar way to that of landscape archaeology, historical archaeology also describes a set of techniques and intellectual concepts which are appropriate for the study of the modern and early modern periods rather than particular themes.

A major attraction of historical archaeology in the context of the present study, is that the contribution of documents has been realigned away from solely using them to provide events and dates but to provide social and historical context for material remains, to explain them in terms beyond their sequential significance. Beaudry has coined the term 'documentary archaeology', of which she suggests that archaeologists: 'develop an approach towards documentary analysis which is uniquely their own' (Wilkie 2006, 15) to distinguish between this and exclusively historical analysis of documentation.

There are no precedents for this more integrated approach to the study of 18th and 19th century mining in the United Kingdom. From elsewhere in the world however, an exemplar in exploring the behaviours which surround the industrial processes at mines is the work of Hardesty, who has investigated mining frontier landscapes in America through archaeological and historical evidence and has provided some important methodological leads. Hardesty's statement that mines must be understood as a complete process, or system (Hardesty 1988, 18), is an important concept in the study of the material remains and a departure from the technique of studying isolated aspects of technology favoured by traditional industrial archaeologists. Understanding the entire process relies not only on identifying all the surviving component parts, but also noting variation in the remains that reflect changes over the duration of the life of the mine.

Hardesty also proposed the idea that a mining frontier comprises a number of (metaphorical) islands, each linked by transportation, communication and economics networks. This he refers to as a 'World System', a term first conceptualised by Immanuel Wallerstien, within which each island is individually and collectively dependent on a variety of internal and external dynamic forces such as boom and bust cycles or variations in mineralisation (Hardesty 1988).

Although specifically developed to analyse frontier mining, the concepts behind Hardesty's methodology are naturally transferable to any mining zone or district, whereby the essential lead provided is that mines and elements of mines do not exist in a social, environmental or economic vacuum and need to be considered as part of a social process or system. This applies whether our scale of analysis is at site level, feature level, or examining the industry within a region as a whole. By following this example, when exploring the explanations for change and continuity as proposed in this thesis, it is not enough to observe these phenomena in isolation, and explanations needs to be sought through a consideration of contexts including economic, environmental, technological and cultural.

Foremost amongst these social processes was capitalism, which was one of the key agencies of change in the early-modern and modern periods and a catalyst of industrialisation. In the context of the topic covered by this thesis, capitalism is defined as per Wallerstein, as 'an historical social system in which capital is used with the primary objective of self expansion' (Wallerstein 1995, 14). It is acknowledged however that outside the constraints of this uncomplicated model the mining industry and the commodification of the metals produced could play a crucial role in wider debates about the growth of industrial capitalism, which, in Dartmoor's case will be a discussion for elsewhere.

Evidence for the genesis of capitalist organization is apparent from an early date in the tin workings of Devon and Cornwall, where private capital and waged labour can be identified in documentation as early as the 14th century (Lewis 1908, 189). By the 1780s, the role of entrepreneurs in the expansion of mining on Dartmoor through investment of capital, is the dominant narrative to emerge from primary documentation and contemporary commentary for the remainder of the period, (Chapter 4 and 5). This has been noted by historical writers but seldom analysed in the light of the material remains (Hamilton Jenkin, 1974, 1981; Broughton 1971; Barton 1967; Buckley 2006).

Johnson has suggested that ‘capitalism is a total system, a formation whose structure penetrates and embraces all, or at least most, aspects of economic, social and cultural life’ (Johnson 1996, 9). It is indeed inescapable that a study of industrialisation, within the period on which this study focuses, has to rely on aspects of capitalism to provide a vital pillar of any framework of inference. But although of core importance, the general context of the developing capitalist system must not overshadow themes specific to locality. A point articulated by Tarlow who expressed the importance of integrating these differing scales of analysis:

> *Regional and local studies should be able to examine the kinds of choices being made by situated individuals in particular contexts. Part of the challenge of producing complex, critical historical archaeology is in the integration of these scales of explanation – from the individual to the global.*
>
> (Tarlow 1999, 267)

Johnson similarly observed that antecedents particular to locality can explain variations in the trajectory of social and economic development in differing groups residing within the core capitalist system (Johnson 1996, 9). New World mining frontiers, of the type experienced by Hardesty for example, are very different to those of Europe. When Knapp wrote that ‘mining is a community of occupation not place’ (Knapp et al 1998, xv) he was probably quite correct with reference to Australia and America but in south-west Britain, communities developed around fruitful ore fields which had been successfully exploited for generations. If capitalism is to provide one pillar of an interpretative framework for Dartmoor mining, it will need to be complemented by the issues of locality and the cultural implications of an enduring industry and its local traditions and antecedents. Indeed it will be demonstrated below that the very basis of the capitalistic system of organization which can be identified in the Westcountry mining industry of the 18th and 19th centuries, evolved in part out of the distinctiveness and traditions of the earlier tin industry in Devon and Cornwall and that distinctiveness and sense of tradition was itself shaped by peoples’ experience of the constraints and opportunities that existed in the natural environment.

1.2 A FRAMEWORK of INFERENCE for DARTMOOR

The existence and enduring character of a mining industry in a place like Dartmoor can be explained in terms of the historical capitalist model cited above (Wallerstein 1995, 14), as a combination of valuable material resources being present and a societal demand for those materials, met by a succession of people willing to prospect, develop and exploit them through the investment of private capital in the hope of achieving financial gain. On its own however, this premise offers a rather linear model which overlooks the material variation within what remains of the mining landscape and the temporal cycles of success and decline which they signify. This landscape must therefore contain far greater levels of meaning than can be explained in a straightforward capitalist model and the further dynamics that lay behind the progress of mining for metals need to be considered if this investigation is to result in wider inference. Variables may include:

- Environmental factors including the mineralogical potential of the district, and other resources available, especially water, which may aid or constrain effective exploitation
- World economics, which dictate fluctuating demand and prices for the metals through consumption
- The influence and adoption of technology
- Social antecedents which may exist specific to locality

A mining industry that is subject to these and other variables over a period of time, more than 200 years in this case, will result in a landscape containing material evidence of the human responses to these factors. The methodology (Chapter 2) asserts that these responses are observable within the archaeological remains and that explanation may be attempted through an analysis that is informed by the documentary record and considered within all relevant contexts (Chapters 3-5).

The Thesis

The impact and development of mining on Dartmoor will be assessed through a multi-scalar contextual analysis of the archaeological remains and historical record of tin and copper mining. The research will explore how historical capitalism developed and provided the dynamics of economy and a social context for growth in the mining industry, as well as influencing the trajectory and particularity of changes to mining that occurred within the study period, manifest through the nature of the field evidence. The study will also examine the decisions made by mining people at local level as to how they could best prosecute their industry within the social, economic and environmental contexts of the time and place.

At a macro scale the investigation will explore how the trajectory of mining progress and the consequent extent and character of the material landscape was broadly shaped by global dynamics such as fluctuating value, cycles of consumption and demand for the metals over the period of study between 1700 and 1914. How for example did capital-based 'mine adventures', evident through the activities of joint stock enterprises and cost-book companies, respond to these global dynamics as a speculative means of accruing wealth. The contrasting evidence of the period before the introduction of a capitalized mining industry, prior to the late 17th century, is also discussed in the light of this interpretative framework and any locally distinctive aspect of capitalism which developed.

Although capitalism provides a primary framework of inference for this research, it does not provide a universal explanation for all the patterns of variability that are to be witnessed within the Dartmoor mining landscape. Growth and decline of mines and mining at individual and regional level, together with choices regarding the use of technology may have been further influenced by a variety of factors that both complicate and enliven the narrative. Examined at a more localised scale therefore is the interface between the environmental opportunities and constraints provided by the unique region of Dartmoor, and the human agency which lay behind the decisions leading to the various forms of intervention. For example the vagaries of the deeper mineral resources in some places made success uncertain and deeper mines required expensive pumping machinery; however, Dartmoor's plentiful water supply provided a cheap source of motive power. These considerations and others would directly affect the viability of a mine, more or less acutely depending on the economic cycle; they required a rational human response at local level to overcome problems or take advantage of opportunities.

The individuals involved are difficult to identify in an earthwork landscape but their collective responses are evident in the field and documentary record, where we may witness their engagement with both the global economics affecting their industry and the environmental issues at local scale. Many decisions were undoubtedly made on the basis of environmental possibility or economic practicability at a site-specific level, or through progressive or conservative attitudes to technology. Some decisions however, must have been determined by cultural conditioning of those involved in mining, following centuries of tradition and cross-generational association with this place, and through their experience of certain elements of the landscape, including its natural resources and evidence of past mining endeavour. The basis of these decisions may be grasped through the study of contemporary documentation while the results of their practical actions will be manifest in the field evidence.

In essence therefore this thesis explores how a broad variety of dynamic forces, at global and local scales, affected the working practices and prosperity of those involved in mining on Dartmoor and how the decisions they made in response to these forces, have shaped the forms of intervention observable in the material landscape today.

1:3 THE WORK OF PREVIOUS WRITERS

1.3.1 Historical studies of Dartmoor mines

Throughout the 19th century mining was an active industry in Devon and an interest in its past by antiquaries and historians was restricted to the study of earlier periods, focussing on the medieval and post-medieval activity, while also attempting to establish the earliest origins of the tin, and to a lesser extent, copper industries (e.g. Taylor 1799, 357-65; Moore, 1829, 356-73; G Borlase 1832, 486-9; R N Worth 1875, 223; Crossing 1889-91; Burnard 1887-90; 1891, 85-111; Baring Gould 1900).

Of the 20th century historians who have included mining topics in more general discussions of Devon, Finberg (1949; 1969, 167-91) and Hoskins (1954) are at the fore. Like their predecessors, both were fascinated by the early tin industry but neither expended any research energy on the 18th and 19th century mining industries. Later in his career, Hoskins conceded that 'A whole book is waiting to be written on the mining history of Dartmoor' (Hoskins 1966, 40) but it would be left to others to advance the subject further.

Although Harris (1968) provided a limited gazetteer of Dartmoor Mines, Hamilton Jenkin's *Mines of Devon* (1974; 1981) was the first attempt at quantifying the Devon mining industry from historical sources and remains the only comprehensive general historical study on mining in the county. Hamilton Jenkin's work was primarily based on documentation and it is clear this author carried out little fieldwork as few of the mines mentioned were evaluated with an archaeological eye, while several undocumented mines are absent from these volumes (see appendix).

The historical study of the Stannaries, the legislative body that administered the tin industry in Devon and Cornwall, which although having medieval origins still had some influence in the late 18th century, has been a fruitful topic for historical research (see Chapters 4 and 5). G R Lewis (1908) provided an historical overview of the Stannaries for both Devon and Cornwall, while Pennington (1973) presents background on issues such as capitalization of the tin industry and the development of the cost-book system. The study of the Devon stannaries has benefited from research by Finberg (1949, 155-84; 1950, 295-310); R H Worth (1910, 21-45), Hatcher (1973) and others. More recently Greeves has added substantially to the understanding of this topic for the earlier period (1987, 145-67; 1992, 39-74; 2003, 9-29).

Dartmoor's copper and silver-lead industries are yet to be the subject of any detailed publications, although Schmitz (1974) study of the economic history of the Teign valley lead mines has offered a basic historic outline in a single district but lacks analysis of field remains.

Two articles, particularly germane to this study were produced by Broughton (1969; 1971); his detailed historical study of the mines in the Birch Tor Vitifer area (1968/9, 25-49) was the first of its kind to examine a series of mines within a 'complex' through historical documentation but with some reference to the field remains and background petrology. *The Land Half Made* (1971, 1-25) was a seminal essay, in which Dartmoor mining was considered in the light of historical context, extrapolated by the author from the documents available to him. Unfortunately the sources are largely unreferenced. Nevertheless, Broughton was the first to suggest the importance of the relationship between investment of capital by outside mine adventurers and the working of the mines at local level.

1.3.2 Archaeology Studies of Dartmoor Mining

The earliest items to discuss the archaeological remains of the Dartmoor metal industries appeared in the 1880s (Burnard 1887-90, 95-112, 223-242) and focussed on medieval and post-medieval tinners' blowing houses, where tin was stamped and smelted. This research tradition has continued through much of the 20th century by R H Worth (Spooner & Russell 1953, 289-328), followed by Parsons (1956, 189-96), Greeves (1969; 1971) and Newman (1995, 185-97), each adding additional survey data. The archaeological evidence of tin working or extraction, as opposed to tin processing and smelting, was largely overlooked in Devon until the 1990s, when published fieldwork and survey results first became available (Newman 1994, 199-238; Gerrard 1992, 6-8; 1996, 67-83; 2000, 60-103).

The first authoritative volume to bring attention to the field remains of Dartmoor's mines of the 18th - 20th centuries, and indeed all the other industries of the period, was Helen Harris's *Industrial Archaeology on Dartmoor* (1968), which complemented Booker's *Industrial Archaeology of the Tamar Valley* published the previous year (1967). Together they represent the inception of publication on Devon mining archaeology, and very much reflect a national trend in the early days of publication of industrial studies at that time, as recognised and discussed by Symonds & Casella (2006, 145).

The only writer so far to have researched any aspect of Dartmoor's mining archaeology at doctoral level, focussing mainly on the earlier tin industry of 1450-1750, is Greeves (1981). This author has also published several articles on individual tin mines of the later period, which rely mostly on documentary evidence but include some field and survey data (1975, 6-7 & 15; 1976, 3-5 &11; 1978, 161-71; 1985, 101-27). Greeves was also joint author of the first detailed study of an individual Dartmoor tin mine, which was Eylesbarrow (Cook et al 1974, 161-214).

Mines recorded using archaeological field methodologies in Devon have been published by both the Exeter (EA) and Cornwall (CAU) Archaeological field units. Mostly in 'grey' format, the Devon surveys include Gawton Mine (Pye & Weddell 1993); Devon Great Consols (Pye & Dixon 1989; Buck 2002) and Bedford United (Buck 2003). Also a survey of Wheal Betsy engine house (Pye & Westcott 1992), which lies within the Dartmoor study area. Earthwork survey and analysis of surface features at several Dartmoor mines, have been produced in grey format by the RCHME (now English Heritage) Archaeological Survey and Investigation team (Newman 1998; 1999; 2003; 2004; 2005). Although undertaken in a research context, the individual and focussed nature of all these site investigations, precludes the more general questions which might be asked if such material was to be looked at collectively.

1.3.3 The Contribution of Cornish Writers

Of relevance to Devon are 20th-century historically based studies of the ‘Cornish’ mining industry, a term which frequently includes the Devonian mines, and on which subject the most prolific contributors are D B Bradford Barton and A K Hamilton Jenkin. Both relied solely on historical sources, including predominantly the somewhat unreliable *Mining Journal*, a periodical, which was heavily biased towards attracting investment in mining. Barton, who is responsible for standard works on the history of both tin (Barton 1967) and copper (Barton 1961), was dismissive of the usefulness of field survey claiming that ‘a square yard’ of documents will ‘reveal far more of substance’ than a ‘square mile of ‘old ruins’ (Barton 1968, 10).

Because the majority of the productive tin and copper mines of the Westcountry were in Cornwall and the industry has needed to identify with a place, ‘Cornish Mining’ has become the universally used term to describe it. As a result, for historians of Cornish Mining, the less important Devon tin and copper mines are often subsumed within this geographical descriptor, or worse they are ignored because they were not in Cornwall.

Bradford Barton for example, was very comfortable citing evidence from Devon mines in his two volumes, which are both entitled *Essays in Cornish Mining* (1968; 1970). Also, in *A History of Copper Mining in Cornwall and Devon* (1961), the latter is included only because of the inescapable importance of Devon Great Consols, a Devonshire mine in the Tamar Valley, which massively out-produced any single 19th -century copper mine on the Cornwall side of the Tamar (*Ibid,* 95). This left Barton with little choice in the title of his book, but with the exception of Wheal Friendship at Mary Tavy, a similarly prosperous though smaller copper mine, he ignores all others in Devon. To economic historians like Barton, the importance of a mine can only be measured by its output; clearly archaeologists cannot accept this as a research principle.

There has also been a bias in some mining history writing, towards promoting Cornish identity. Most accounts of Westcountry mining have been written by historians with strong connections or involvement with the mining industry, indeed some were miners or mining engineers themselves, such as Buckley (2007) and Earl (1968), or had ethnic origins within Cornwall in the case of Hamilton Jenkin and Penhallurick (1986). For them, not only is this topic about mining history and technology but their accounts set out to promote the *Cornish* mining industry, which was still active when they wrote these works, and the cultural identity of the Cornish. Within the resulting construct of ‘Cornishness’, the contribution of any outsiders to the story, would run counter, so there is little room to include Devonian mines, ignoring their significance as part of a wider mining perspective.

Penhallurick for example dismisses the Dartmoor tin industry as ‘a scattering of unimportant tin mines’ (Penhallurick 1986, 115), though fails to define to what level of ‘importance’ he refers. In Bradford

Barton's *A History of Tin Mining and Smelting in Cornwall* (1967), references to Dartmoor's tin mines are relegated to the footnotes, whilst the author continually reminds the reader how insignificant Devon's contribution was, eg: 'In the nineteenth century mining on Dartmoor was never of great importance…' (Barton 1967, 111). Again the term 'importance' is not defined but clearly refers to output rather than historical, cultural or archaeological significance.

Hamilton Jenkin was another Cornishman with an impressive publication record on Cornish Mines. Later in life however, he wrote *Mines of Devon Vols 1* (1974) *& 2* (1981) because, he claimed, no Devon historian had attempted the task, implying that in his view, cultural identity is a qualification for those engaged in the writing of these histories.

As will be apparent in the discussions that follow, it is an inescapable fact that the Devon and Cornwall mining industries are firmly linked historically and until the present the narrative has relied almost exclusively on Cornish historical sources, collated by historians of 'Cornish Mining'. An important consideration for researches into Devon's mines must be to highlight this county's unique contribution but also integrate it more fully into the general narrative of Westcountry mining. This thesis and the archaeological data presented within it, is well placed to make inroads into this imbalance and offer a fresh perspective on Devon's mining industry, especially that of Dartmoor.

CHAPTER TWO
METHODOLOGY

2.1 SUMMARY

The methodology developed for this thesis relies on investigative fieldwork supported by targeted documentary research as a means of gathering primary archaeological evidence of mining activity on Dartmoor. The research aims set out in Chapter 1, are addressed through an analysis which examines the temporal and functional relationships between situated material evidence within the contexts of the social processes associated with their creation, use and abandonment by humans in the past.

The research has focussed on two specific behaviours manifest in the field archaeology and documentary record of a number of case studies. These are:

- Mining for the tin and copper ore
- Dressing (i.e. processing) the ores

2.2 PRINCIPLES OF ARCHAEOLOGICAL INVESTIGATION APPLIED TO MINING LANDSCAPES

The core practical tasks and intellectual processes associated with archaeological investigation have been outlined by Bowden (1999). These are:

- Look at what is there
- Consider, and try to understand, the component parts and how they relate to one another
- Assess how the whole relates to its contemporary context (whether on a local, regional, or national level) and to comparable examples recorded elsewhere (Bowden 1999, 23)

The material evidence of mining on Dartmoor survives in the form of earthworks, turf-covered foundations of ruined structures and some very fragile, partly-standing ruined buildings. Unravelling any meaning or evidence of change from such remains relies first on establishing their location, frequency, morphology, function, associations and relative chronology to enable a process of reconstruction of separate features, individual sites and whole mining landscapes on which to base an analysis. This can be achieved by an empirical process of careful observation and recording at a selection of separate sites, cataloguing and comparing the different types of remains and their occurrence. Function and morphology are not always immediately obvious if evidence has been altered post-abandonment but may often be established through deduction by consideration of how various components relate to each other. For example, certain categories of evidence are indicative of particular processes and the observation of one form will, through known associations within processes, lead to the discovery of others which may not be so clearly defined. A heap of mine waste for example, may be indicative of the presence of a mine shaft which has been capped and is no longer visible. Similarly, the earthwork remains of a leat may have once led to a waterwheel pit which has been effaced or damaged, thus helping resolve any lack of clarity which my be inherent in disturbed, partly erased or morphologically challenging evidence.

Through a cycle of recording, interpolation and re-evaluation, what at first sight might appear to be an intractable jumble of amorphous features, can be ordered, placed within a relative chronology, interpreted and reconstructed, thus enabling comparison with other examples, further discussions of their significance and how they relate to their environment and contexts.

2.3 METHODOLOGY

The methodology has five sequential components or steps:

- Archival and documentary research – compile a desktop survey and create a database
- Fieldwork, reconnaissance, recording, survey – expand the data base
- Interpretation and reconstruction of field data, integrate field and documentary evidence
- Establish contexts – environmental, economic, historical
- Consider field data in the light of contextual research and analyse cultural significance in terms of thesis objectives

2.3.1 Archival and written sources

Documents, maps and contemporary photographs have a major role in the discovery of mining sites, together with the interpretation of certain elements within those sites, and they can provide details of chronology for those elements. Often however, they may also provide clues as to contemporary social context (see Chapter 5).

The county record offices of Devon and Cornwall contain a large quantity of primary sources pertaining to individual mines on Dartmoor. These include: legal documents, deeds and indentures; correspondence; winding-up papers where companies have gone bankrupt; lawsuits such as disputes over water rights; sale particulars with details of materials on site; share prospectuses; company papers; cost books listing expenditure and items purchased.

Additionally, for most mines of the 19th and 20th centuries, and for some within the 18th, there are newspaper articles, particularly from local papers such as *Exeter Flying Post, The Sherborne Mercury* and the *Plymouth and Devonport Weekly Journal*, each of which contain journalistic reports, sales of shares and auctions of material from defunct mines. After 1836 the *Mining Journal* is available. This is a weekly newssheet, dedicated to the business of mining worldwide, which although heavily biased towards attracting investment in mines, can be a useful source of information about them. The majority of material from the *Mining Journal* has been collated and summarized by Justin Brooke and is available through the Westcountry Studies library in the form of the *Brooke Index*, divided into parishes and cited as 'BI' followed by parish in this thesis.

Caution is needed when using periodicals to inform fieldwork because references to operations on the ground often refer to what was aspired to, rather than what actually existed. In the case of Smith's Wood Mine, for example, a correspondent in 1860 described the discovery of a tin lode as 'one of the most extraordinary discoveries ever made' (*MJ* 10.11.1860) and despite reports that 'many tons of tinstuff had been raised', all that remains at the site today is a very short adit and a shallow blocked shaft, which negate the fact that any ore at all was raised from this mine.

Mine plans and sectional drawings prepared for mine companies are available for a select few mines. However, these maps, when available, offer only a snapshot in a mine's working life and, depending on at what stage of the mine's overall career the map was drafted, are usually incomplete. They mostly depict underground activity but some exceptions include surface features. The section drawings of New

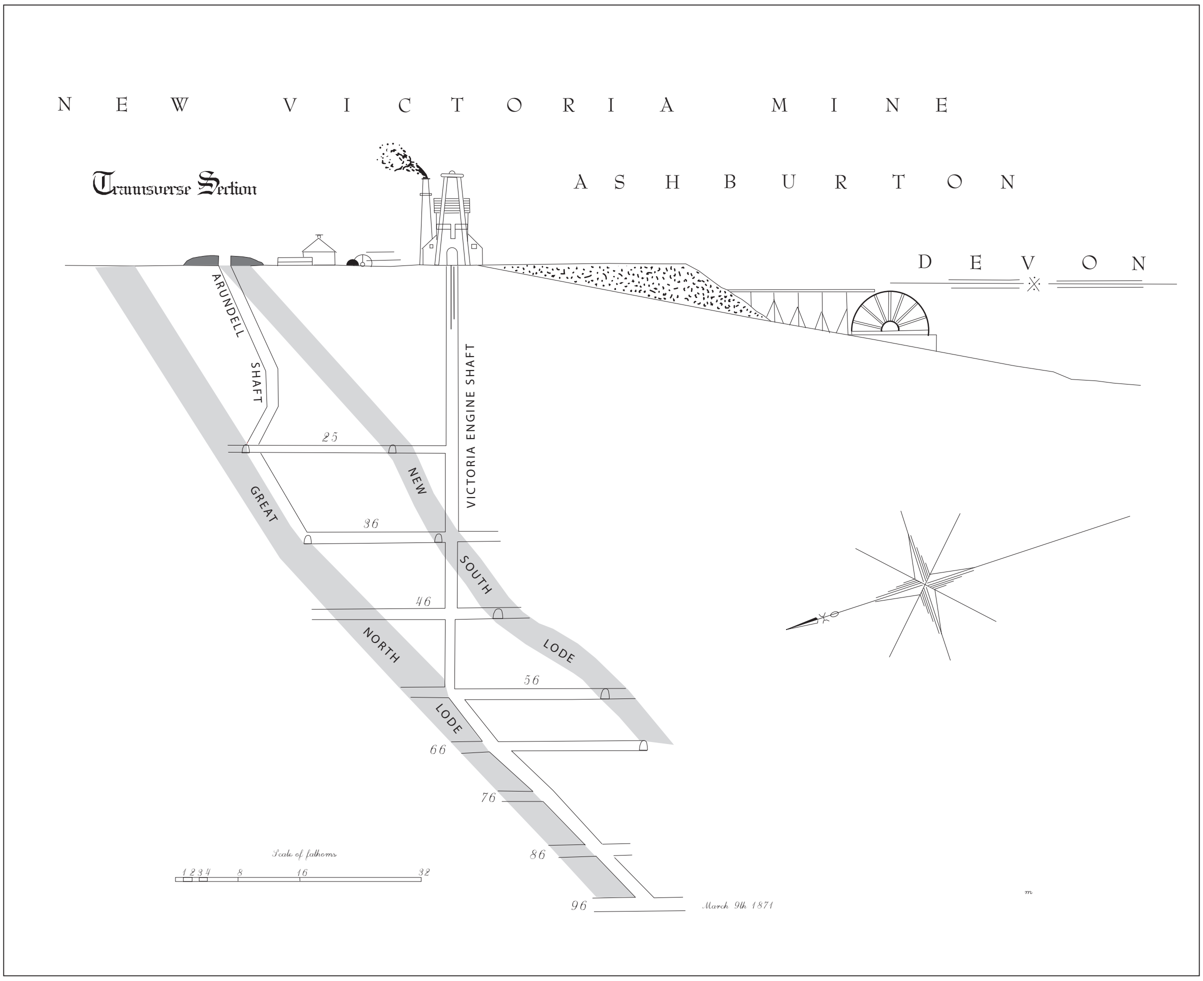
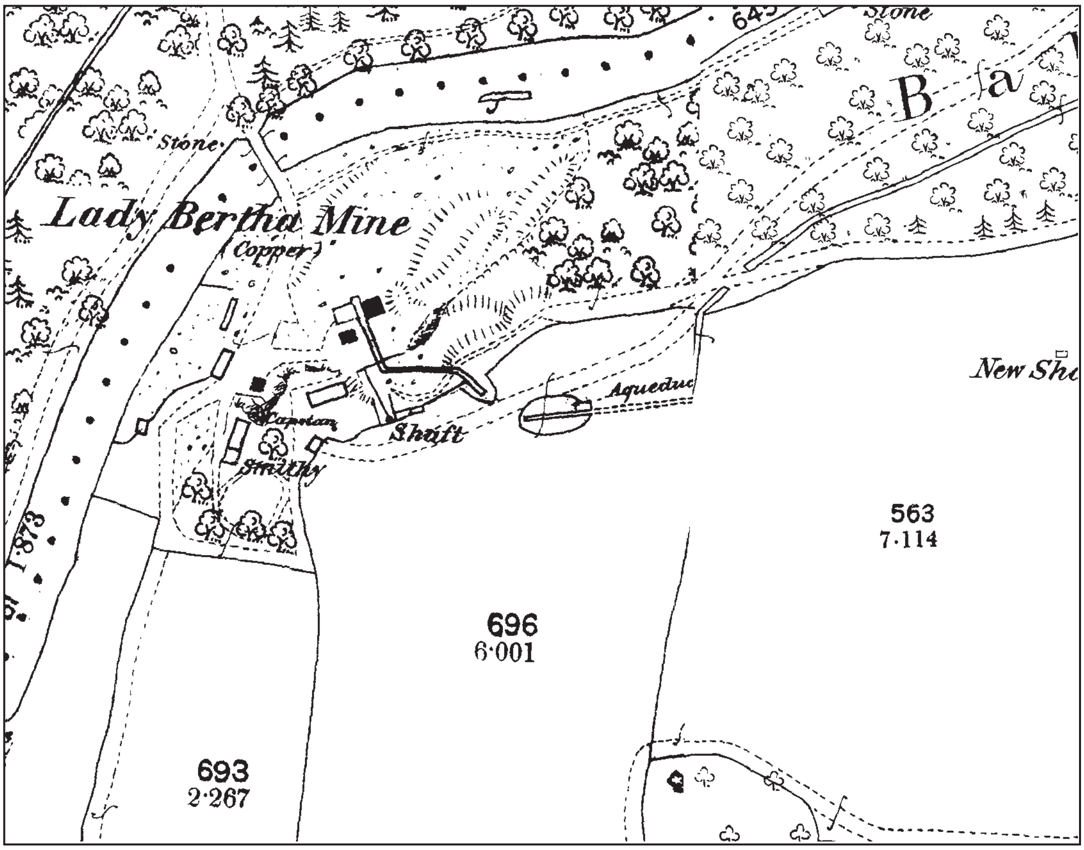
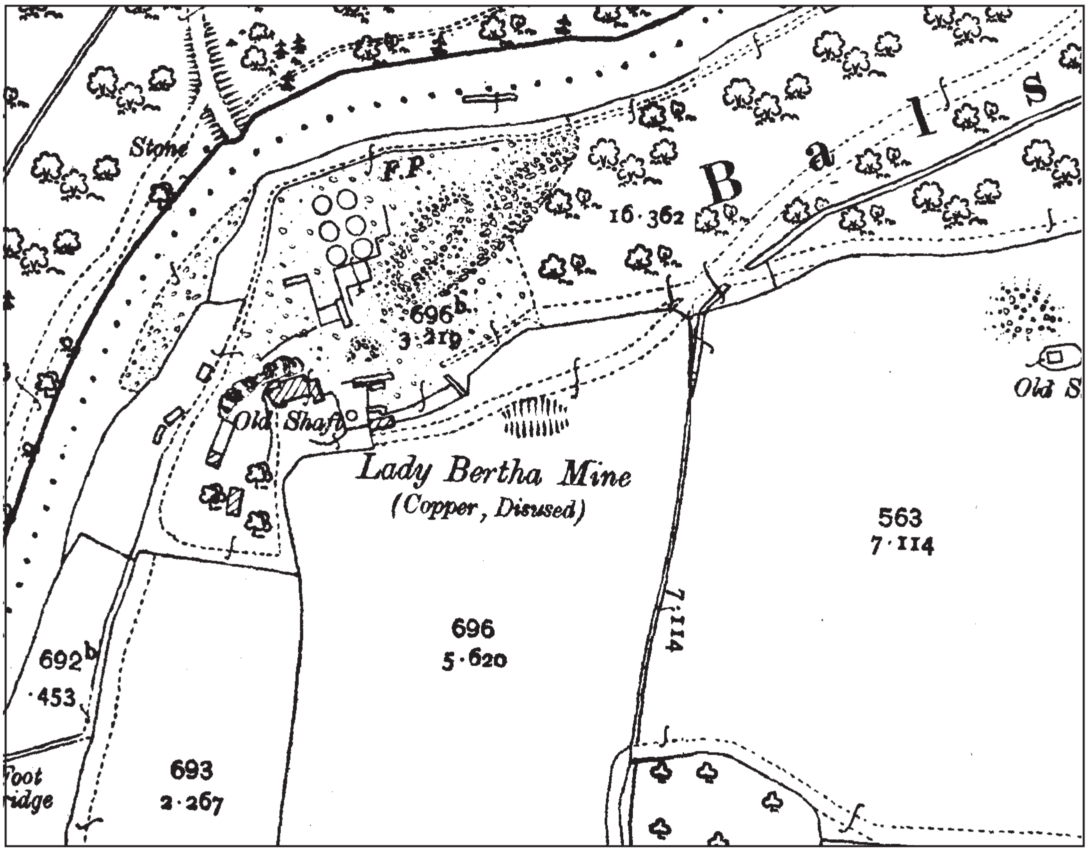


Fig 2.1 Redrawn sectional view of New Victoria (Arundell) mine based on the abandoned mine plan of 1871. (after DRO AMP R100b)



OS 1882-4 25-inch first edition map extract



OS 1906 25-inch second edition map extract

Fig 2.2 Map extracts from 25-inch scale 1882-4 OS 1st edition (top) and 1906 2nd edition (lower) maps showing alterations and additions to the surface evidence at Lady Bertha Mine.

Victoria Mine (Fig 2.1) offer an excellent example, depicting the positions of shafts, levels, the engine house, waterwheel and ancillary buildings (DRO AMP R100b).

Historic Ordnance Survey (OS) maps at 1:2500 (25 inch) scale offer a more consistent cartographic source for informing fieldwork. First edition (1870-80s) maps will often depict in detail, mines recently abandoned and those still operating at the time of survey. Between the 1st and 2nd edition (1905) the installations depicted may differ at the same mine, providing useful information about changes in layout, additions and abandonment. At Lady Bertha Mine, between 1884 and 1906, a dressing floor for refining tin was added to a mine previously worked for copper (Fig 2.2).

For the later 19th and early 20th century, contemporary photography of mines, some still in use and others recently abandoned, offer a means of shedding light on aspects of field remains; like maps and plans they offer only a static glimpse into a mine's working life although they recorded a crucial though neglected period in Devon's mining past. Many of the best-known Dartmoor examples have been published making them freely available for study (e.g. Greeves, 1986; 2005; Hamilton Jenkin 1974; 1981; Richardson 1992).

The availability of documentary material is not consistent over the whole population of mines, which if mines are to be examined collectively is an important factor for consideration. Holne Chase Mine possesses remarkably complete earthwork evidence of the operation, including an extensive dressing floor, but so far only mere fragments of documentation have come to light, mentioning its name and that the mine existed in 1872 (Newman 2006). Whereas East Brookwood Mine, a prospect with unremarkable field remains which operated in the 1860s, has a comprehensive range of documents available, including a cost book, tutwork setting book, ledgers, bank book, share registers and general papers (CRO STA/I/25/1-6). In cases such as Holne Chase therefore, reconstruction has to rely mainly on analysis of field evidence alone (below).

2.3.2 Sampling methodology

The desk-based survey and database

To compile a useful body of data, the first objective has been to establish the total population of available subjects by means of a desktop study. This has been achieved through collating bibliographical, cartographic and documentary references described above to form a database using Microsoft® Access®. Examples of data fields populated from desktop sources include mine names, location (NGR) and parish, types of ores worked, bibliographical references (see appendix).

For many of the mines there are several associated documented names, as ownership passed between companies. At a site just outside Ashburton for example, referred to on OS maps as 'Druid Mine' (OS 25-inch 2nd ed. 1905), a copper mine operated under six separate companies between 1852 and 1876, each providing the mine with a different name (Newman 2003, 173-218). In other cases independent mines located close to one another may have been amalgamated under a single company. North Dartmoor Consols demonstrates this point, where Wheal Frederick, Curbeam and Rattlebrook Mine were brought together under the single title in 1869 (BI, Lydford) Within the database therefore, where duplicates have been identified, the name most usually used is termed the 'primary reference' while alternative names are listed also. An additional site number is included where archaeological evidence is known.

The resulting database informed the fieldwork that followed and a list of candidate sites, where fieldwork might be viable, was collated. This list was further refined on the basis of the practicality of fieldwork, including such issues as access, permissions and vegetation cover. A working shortlist of sites which merited detailed inclusion in the body of research material was then prepared (Tables 6.1; 6.2), based on the following criteria.

- That the site was within the elected study area, DNP and its immediate borders
- That either tin or copper were worked from or prospected for at the site
- That surface evidence of mining and/or associated infrastructure survives
- That fieldwork at one of the levels (1-3), described below, was possible
- That the site, or features of the site, could be linked through documentation to the period of the study, or through morphological similarity to mines of the period (see chronology below)

By undergoing this process and using these criteria, it has been possible to avoid choosing subjects on the basis of any preconception of what the field remains associated with each site may contribute to the research, therefore providing an unbiased sample of material.

2.3.3 Field Methodology and recording

The study material: mining surface evidence

Field data for this study comprises surface evidence for mining and associated processes. Mining is essentially an underground activity and it has been argued by both Burt and Roe that a full understanding of mines may only be achieved through knowledge of what lies underground, in addition to that which survives on the surface. Burt for example, when discussing the mapping of mines as a means of studying them, claims that this can be an 'imprecise' or 'misleading' exercise, as maps are concerned only with surface features while the nature of mines is of 'invisible underground labyrinths' (Burt 1999, 345). Furthermore, Roe has argued for, and demonstrated the benefits of, archaeological investigation of both surface and underground remains as part of the same process, emphasizing the seamlessness of these two components of the metal mining landscape, which to the miner, was 'part of the same world' or landscape (Roe 2007, 12).

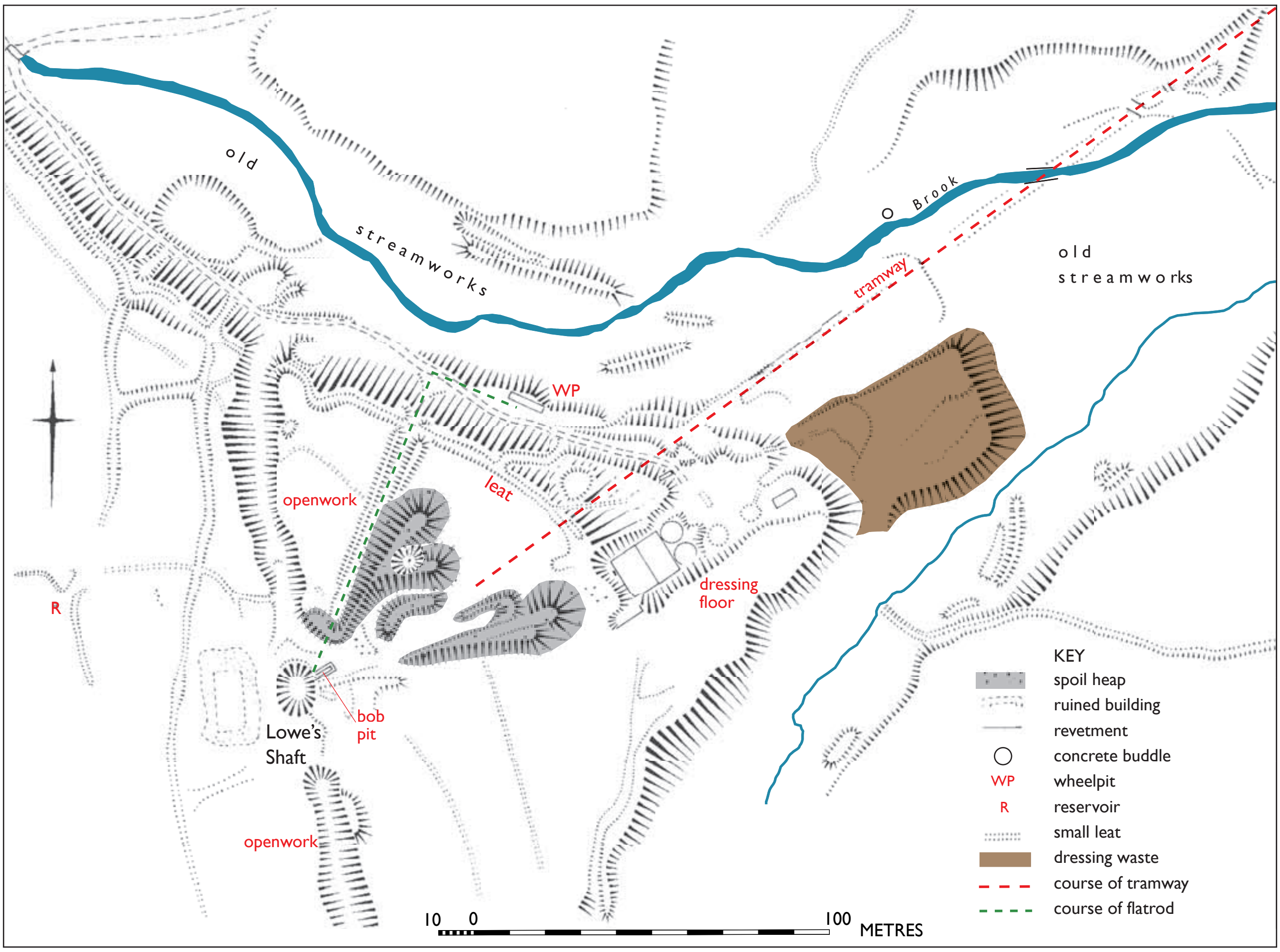


Fig 2.3 An earthwork survey of part of Hexworthy tin mine, showing the late 19th-century Lowe's Shaft, sunken onto a lode previously worked using an opencast technique, probably two to three centuries earlier. Large finger dumps of mine waste extend from the head of the shaft and a flat-topped heap of dressing waste is spread below the dressing floors.

These are both valid and important considerations and, where possible, analysis of underground elements will always be useful. However, in this thesis it is argued that investigation and analysis of surface remains alone is an extremely effective method of understanding mines and mining landscapes. Recent studies looking at areas of North Wales (Jones *et al* 2004) and Cornwall (Sharp 1993; Herring & Thomas 1990; Herring *et al* 2008) have all demonstrated the strength of this methodology, and provided data on the extent, layout and functional aspects of mines, without the researchers ever venturing below ground.

Many of Dartmoor's mines are completely or partially inaccessible underground due to blockages, flooding and shaft capping. In these cases, underground investigation is not currently an option and the surface remains provide the only field evidence for the extractive activity. It is at least possible to attempt an informed estimate as to the importance and success of the mine from the surface data and consideration of what lies below ground can still form part of the analysis.

Frequently, the evidence of shafts and adits provide clues as to what may have existed below ground; the extent of spoil heaps, the existence of tramways, hoisting equipment and pumping installations are all indicators of below-ground activity. Crushing facilities and dressing floors, where ore was concentrated, provide testimony that those working the mine had serious intentions and hopes of high output, but the presence of tailings (dressing waste) produced by the dressing machinery, such as the large heaps at Hexworthy Mine (Fig 2.3), is a sure indicator of actual production, and the quantity may hint at its duration.

Field Methodology

Following a programme of reconnaissance, mine sites and landscapes have been visited and examined with preliminary analysis of the surviving remains undertaken on site. All observations were recorded or surveyed at one of the levels set out below and further analysis carried out in the office. As data built up, comparative and cumulative observations regarding interpretation and chronology were logged, enabling a reconstruction of the extent of the mining locations and a detailed assessment of what lay within them during the study period. The separation of early (before 1700) and later material was an important part of this process, as was the identification, classification and association of various individual components, which make up the remains of an 18th - 20th century mine.

Recording

Recording was undertaken at levels appropriate to the condition and extent of the remains, in accordance with RCHME (1999) guidelines, most sites being suitable for level 1 or 2 recording. Where possible and practical, large-scale surveys at level 3 have been undertaken.

Fieldwork levels of recording

Level 0: Desktop No fieldwork undertaken. Where a mine or site has not been visited as part of this research due to access, safety or other reasons. The location of the main features are established from cartographic and documentary evidence as part of the initial desktop exercise but no field description exists.

Level 1: Reconnaissance Visit site, establish the character and location of the main features and log observations. Take measurements if possible.

Level 2: Mapping Survey at 1:2500 scale based on existing OS mapping, adding measured data where needed or alternatively, undertake new complete measured survey at 1:2500 scale. Record and log all observations.

Level 3: Survey Earthwork survey at scales of 1:1000 and 1:500.

Technical information

Data capture for the large-scale surveys of mine earthworks and ruined structures at level 3 was undertaken using either a Trimble® SC400 dual frequency global positioning system (GPS) or Trimble® 5600 Total Station Theodolite. After processing, data from these instruments were downloaded onto a computer into a CAD environment, from where it was plotted onto drawing film then taken into the field for the addition of further measured data and annotation. Hachured earthwork plans were produced, some of which are presented here in full while others have been simplified from the originals. Both hand-drawn and digital illustration techniques have been used in the preparation of the hachured plans.

Classifying the Field data

A number of additional tables in the database were populated following site recording and survey. This included, where possible, certain sub-categories of field remains, which are essential to the understanding of both an individual mining site and to a collective overview of the thematic analysis that follows. Measurements were taken as part of standard recording procedure though their relevance is mainly used to help with comparative descriptions; they are included in the tables but do not form part of a statistical analysis.

Classes of field remains

- Wheelpits – size, function
- Leats – source, destination, associated machinery and processes, length
- Stamping mills and dressing floors – size, type, power sources, associated features
- Horse Whims – location, function
- Flatrod systems – length, power source
- Engine houses – location, size, function

Omissions

There is some potential for the skewing of data, not because of the choices for inclusion, but from omissions of certain important mines for a variety of practical reasons. Owlacombe Mine, one of South East Dartmoor's largest tin mines for example, is excluded from the archaeological study because access to the site was not granted by the owner. This situation applies to at least four other mines known to have extensive field remains, which are listed in the appendix. Similarly, vegetation and a policy of demolition in the past have made much of Wheal Friendship in Mary Tavy, Dartmoor's most productive (Burt et al 1984, 57) copper mine, either inaccessible or have neutralized the archaeological remains due to destruction of major diagnostic elements known to have once existed (OS 25-inch 1886). There is also the possibility that the lower levels of survey (1 and 2), when used at extensive, complicated sites may lead to slight but significant details being overlooked in comparison with sites recorded in greater detail. However, the sample, including detailed exemplars, is large enough to reduce the significance of such omissions.

Analytical Themes

Analysis of the mine sites and landscape remains has been undertaken thematically, based around feature-classes set within broader themes. (see Table 6.4). The themes reflected in the headings in chapters 7 to 9 are:

- *Prospecting and extraction:* discovering lodes, underground access, pumping and draining of water, hoisting of extracted ore and waste
- *Processing:* crushing, refining, and disposal of waste
- *The supply of water:* to power pumps and processes

These themes represent the main surface material remains of mining on Dartmoor.

2.4 CHRONOLOGY

The biggest challenge in investigative field survey is the matter of establishing absolute dates for the individual entities recorded. Relative dating, where separate entities may be seen to have chronological relationships, is straightforward if, for example, a negative earthwork such as a trench, pit or water channel uniformly traverses one or more pre-existing earthworks. However, provision of absolute dates has to rely on either documentation or dateable excavated material. The latter is not available for any Dartmoor mines but documents do provide some quite precise dating information, especially for the 19th century, during which period records are most numerous.

For the purpose of this thesis, there are five levels of date precision applied to field evidence discussed in the text and presented in the tables.

Absolute: Where an entity that remains in the field is known to have been installed on a particular date, established from reliable documentary sources.

Associative: Where a secondary entity, not itself documented, is associated with entities that are subject to an absolute date; a leat for example, where associated with a dated waterwheel pit.

Relative: Where an entity may be seen through its relationship with others to either pre-date or post date those for which an associative or absolute date has been established (*terminus post quem* and *terminus anti quem*)

Comparative: Where the date of an entity may be closely estimated by its similarity with others of known date at the same or other sites.

Assumed: Where a mine is known to have been operating at a certain date or dates but individual elements are not recorded; an approximate date may be postulated on the basis of the documentation available if they conform with the assumed chronological standard for the class of feature.

Where any doubt exists, qualifying information will be provided on a case-by-case basis. A reliance on documented dates also means that the earlier the mine was operating, the less likely it is to have much detail regarding dates. In the 18th century, most accounts of mines come from secondary sources; many, including Kalmeter in 1724 (Brooke 2001), Swete (Gray 2000), Hatchett (Raistrick 1967) and others referred to mines in work at the time of their writing as a statement of fact. These sources have to be considered reliable but qualified assumptions have to be made regarding how what they are describing relates to field evidence, where individual elements are rarely mentioned specifically. It is not possible to establish precise working dates of any tinwork that was active before the study period, i.e.1700; even in the rare cases where documentation survives it is mostly impossible to be certain that field remains can be related to any dates mentioned, but their relative earlier date can be postulated if the remains conform morphologically with processes known to be 'early' as described in Chapter 7. This latter principle has also to be applied to any 19th century mines where little or no documentation survives.

As individual mine locations were reworked on so many occasions it is not possible to claim an earliest date for them from documentation. Dates of named mines therefore only apply to the period they were operating under that name.

The above methodology will provide ample data (see Chapter 6-9) to meet the demands of the research aims outlined in Chapter 1, but the first task in presentation of the research is to explore the various contexts within which this material will be interpreted, commencing with geology and economy (Chapter 3).

CHAPTER THREE
ENVIRONMENT AND ECONOMY

3.1 MINERALISATION

Mineralisation is the essential environmental context in any consideration of past mining; not only does the existence of a mining industry depend on the presence of the materials sought, but the response of those seeking it should be proportionate to the extent, richness and accessibility of the ores. It is important therefore not just to acknowledge the existence of these resources, but also to consider the combination and form of opportunities which the unique character of a locality may offer as well as any constraints it may impose.

3.1.1 Geological Events

The earliest dateable rocks in Devon were formed in the Lower Devonian period, 395 million (Ma) years ago, and comprise sands, muds and intermittent deposits of calcareous material which settled and accumulated as silts beneath the sea, later to become compressed by their own weight to form sandstones, shales and limestones. The process of sedimentation and consolidation continued until the end of the Carboniferous era, approximately 280 million (Ma) years ago and several zones and time periods are represented in the strata (Fig 3.1) (Durrance & Laming 1982, 7).

In the later Carboniferous period there occurred a series of tectonic events, collectively known as the *Variscan Orogeny* as described by Durrance & Laming (1982, 10). Folding, faulting and contraction of the various sedimentary layers generated great frictional heating between plates, melting the lower structures and forcing an intrusion of magma from below. The magma then cooled and solidified to form the granite batholith of the south west peninsula. Only a small portion of the upper sections of the batholith is visible at surface, forming separate bodies or plutons, including the massifs of Bodmin Moor and Dartmoor. The granite tors which characterize these moorlands are the visible outcome of this event. Granite was derived from the melting of sedimentary rocks and is composed of four major minerals, quartz, feldspar, biotite, mica and accessory minerals including tourmaline. The heat generated by the rising magma also transformed the composition of the older rocks in the contact zone around the granite creating a concentric ring of baked sedimentary rocks surrounding the pluton of approximately 0.75 and 3.25km wide at surface and known as the Metamorphic Aureole (Fig 3.2) (Durrance & Laming 1982, 99). The collective term locally for all sedimentary shales and slates, whether affected by this process or not, is ‘killas’.

During the period of cooling, magma, along with the metamorphosed rocks of the aureole, contracted fractured and underwent some movement, producing fissures within and between the rocks. Some of these would be filled by poryphry to form Elvan Dykes of hard quartz, while others became filled by

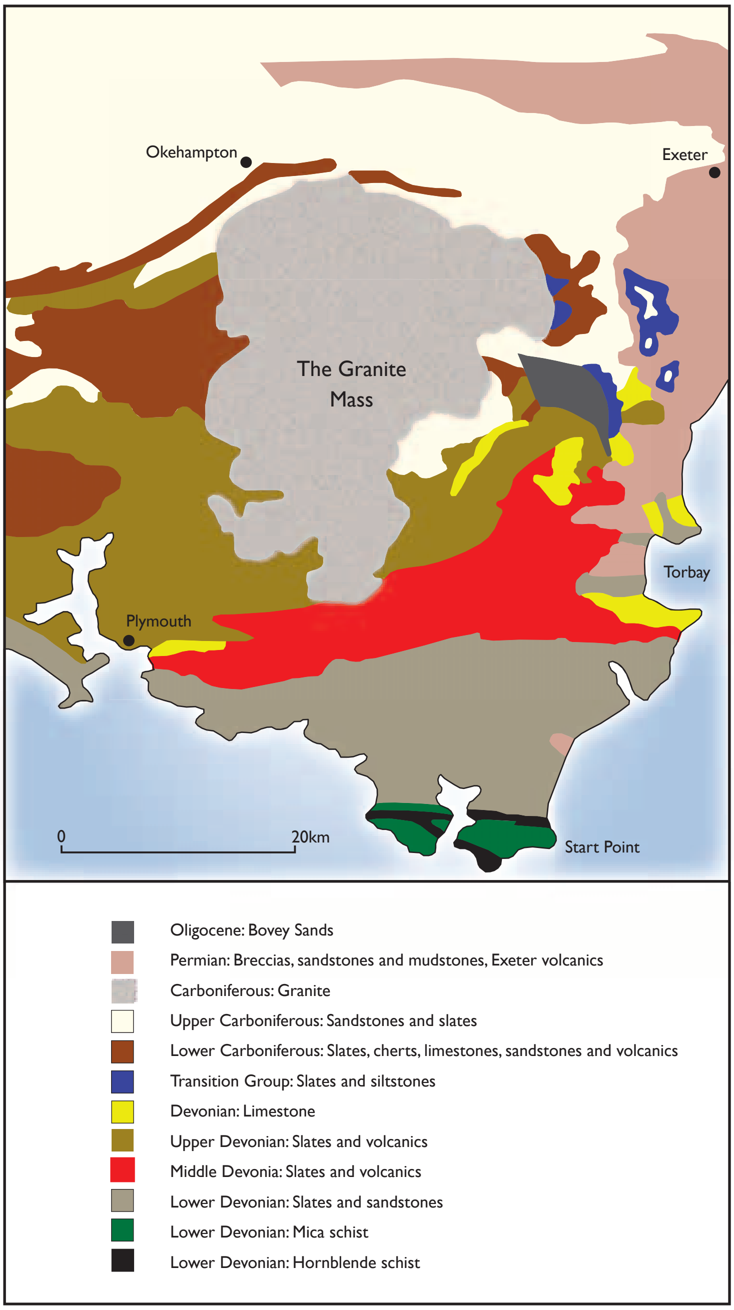


Fig 3.1 The Geology of south Devon, showing the granite mass of Dartmoor as an intrusion within the Devonian slates and Carboniferous slates, cherts and limestones. (after Durrance and Laming 1982, redrawn)

hydrothermal or metalliferous veins. Hot gases and mineral rich solutions emanated from the magma in areas believed to have been still molten after the majority of the batholith had cooled. These areas are termed 'emanative centers', and the location of the major examples coincides with the loci of mining districts. Upon solidification, the metallic veins or lodes were formed (Dines 1956, 5-7).

The uplifting process, which occurred as one of the outcomes of the *Variscan Orogeny,* resulted in the formation of mountains rising from the sea to form the landmass that was later to become the south-west peninsula. This was, from the very start, subject to weathering and erosion of the upper layers,

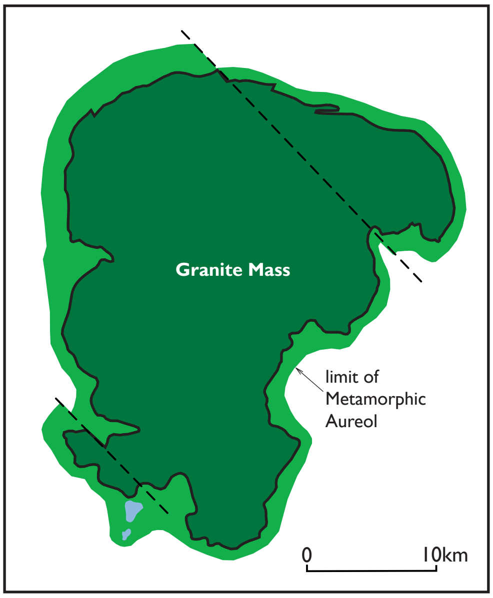


Fig 3.2 The granite mass of Dartmoor showing the Metamorphic Aureuol surrounding the granite. (after Durrance & Laming 1982, redrawn)

but particularly during the Permian and Triassic periods, causing extensive deposits of alluvium, eroded from the upland, to be washed down and build up in the river valleys of Devon (Durrance & Laming 1982, 11-12).

3.1.2 Formation and character of the mineral veins

The elements contained within the mineralized solutions which flowed into the fissures, solidified at varying temperatures to form metallic rocks. Cassiterite (tin oxide SnO^2) hardened at the highest temperature, whereas the sulphides such as Chalcopyrite ($CuFeS^2$), the main ore of copper, Galena (lead sulphide PbS) and Blende (zinc sulphide ZnS) cooled at progressively lower temperatures. The metallic ores are therefore found in zones spreading from the emanative centres arranged in that order, the tin being the deepest, closest to the source of heat (Dines 1956, 7). Complete examples of this model of zoning are, however, rarely found in reality, due to the absence of key minerals at specific points, either because not all the minerals actually formed in the first place, or erosion has removed some or all in some places. The hydrothermal veins are found in both the granite batholith and the metamorphic aureole but the combinations of metallic minerals within each differs.

During the Permian and Triassic erosion, any Metamorphic rocks that remained covering the granite boss, together with the upper sections of the granite itself, were dispersed over millions of years, taking with them the upper levels of the mineral veins; only the lower sections of the cassiterite veins remained *in situ* within the granite while the weathered material from the upper sections became redeposited in the form of placer or alluvial tin in low lying valleys, basins and river plains (Durrance & Laming 1982, 128).

Off the granite, in the areas still covered by the baked sedimentary rocks of the Metamorphic Aureole, a wider range of minerals survive *in situ*, including tin, copper, lead, wolfram and iron. Silver and manganese occur in isolated areas together with minor minerals such as magnetite, micaceous hematite and arsenopyrite or mispickle (arsenic, As).

In Devon and Cornwall hydrothermal veins or ‘lodes’ follow a predominantly ENE trend. Less common are veins oriented ESE known as ‘caunter’ lodes but it is usual to refer to both these variants as east – west lodes. The higher temperature mineral veins of tin and copper are always found following this trend as well as some that formed at lower temperatures. Higher in the strata there is also a smaller number of fissures following a north – south orientation which when mineralized are referred to as 'cross-courses' and may contain lead and zinc. The lead mines of the Teign valley on eastern Dartmoor follow such a north – south cross-course (Perkins 1972, 101).

In addition to the vein material, the wall rock surrounding the fissures may have become mineralized, referred to by the miners as 'capel'. Where sufficient quantities of ore existed this phenomenon was called a 'carbona' (Dines 1956, 15) and although difficult to extract because of the larger quantities of gangue it contained, this material could be worked for a profit when ore prices were favorable and sufficient quantities could be extracted to make the processing of them worthwile.

A major outcome of the erosion of the granite, along with its cover of country rock, is that the surviving veins of cassiterite tend to be fairly shallow. This is one of the main geological factors that makes the larger granite bosses of Dartmoor and Bodmin Moor of less economic importance in the 18^{th} to 20^{th} centuries, when compared to the low lying area of Camborne for example, where the granite intrusion was contained beneath the country rocks with little erosion. There were therefore two main geological conditions to confront the miners within the Dartmoor mining region. Within the granite there were only tin lodes, which represented the lower sections of the veins and tended to be the less rich portions and not sustained at greater depth. The upper sections had been eroded and deposited as alluvial or stream tin, hence the more easily accessible alluvial and eluvial tin sources, which had been available to previous generations of tinners (Chapter 4). The working of lodes in granite is further disadvantaged by the extreme hardness of the rock; although the backs of lodes could be worked at surface, with very few natural fissures and faults, granite is very difficult to work without explosives. In the metamorphic aureole or 'killas zone' tin, copper, lead and several minor metals could all be mined, though usually at greater depth than within the granite. Killas is much more readily workable using simple hand tool techniques, taking advantage of the natural fractures and faulting of the rock. The location, quality and workability of the various ores was therefore highly variable on Dartmoor. Occasionally, tin ore of exceptional grade was sent to the smelters, as recorded from Hexworthy Mine in 1891 (Barton 1967, 190), although undoubtedly on a small and non-enduring scale, but on the whole the district was not as well-endowed mineralogically as others in the peninsula; as Durrance and Laming (1982, 126) put it, 'with few exceptions their ore has not been outstandingly rich'. The mine adventurers' ability to work these lodes to financial advantage therefore was more dependent on broader-scale economic factors than perhaps in other areas.

3.2 ECONOMIC CONTEXT: CONSUMPTION AND DEMAND

(nb: *data used in the following production tables, have been mainly derived from Schmitz 1979, whose statistics have been selectively entered into an MS Excel spreadsheet and expressed as graphs, specific to the present purpose. Schmitz presented his figures in (metric) tonnes whereas other figures used from Hunt's Mineral statistics and HM Inspector of Mines are in 'long' tons, and Stannary figures (Lewis 1908, 252) have been published in thousand-weights (1200lb). For consistencies' sake, thousand-weights have been converted into tons and where appearing alongside Schmitz figures the tonnes equivalent is in brackets with a conversion rate of 1 ton = 1.017 tonnes.)*

3.2.1 Introduction

The dynamics of world economics, patterns of consumption and the resulting fluctuation in ore prices are highly complex and well beyond the scope of this study. Nevertheless, these issues were crucial to the existence, success or failure of individual mines and mining districts and were a major influence upon those who wished to invest capital in the exploitation of metals. It is therefore necessary to consider the Dartmoor mining industry within the context of contemporary consumption, and the socio-economic agencies that created the fluctuating demand for metals and dictated the pace of change. Patterns of consumption varied as society embraced new uses for the materials, while established uses faded from fashion. The availability of metal resources from other parts of the world, as affected by world events, was also a factor in meeting the demands of consumption and directly influenced the economics of home-produced metals.

The bulk of the demand for tin prior to the 18th century came from pewter and later from tinplate, both of which were controlled and well-documented industries which have been the subject of historical studies (Hatcher & Barker 1974; Minchinton 1957; Jenkins 1995). The use of copper has been less specialized; pure copper and its main alloyed derivatives brass and bronze were used on a diverse scale for producing a variety of products for which insufficient detailed information is available to collate any meaningful correlation between consumption and production through an examination of individual uses and fashions. Although brass has been considered with reference to its importance to one of its production centres at Bristol (Day 1975), and its production has been discussed for the pre-1800 period (Hamilton 1926), the industries associated with brass and with bronze do not have specific histories devoted to them in Britain as a whole and indeed this would be a difficult task, given the massive and dispersed nature of their consumption. Historians concerned with copper, such as Prain (1975) take a generalized world view of the subject, which is not sufficiently detailed for the purpose of understanding consumption with relevance to British mining.

Within the constraints of the available data, the following is a summary of the uses and context for copper and tin, from which only very modest inference can be made as regards change at a local level. It must be taken into consideration, that many other sources of tin and copper were available outside south-west Britain, and for tin in particular, Cornwall massively out-produced Devon for the entire period of this study (Chapter 4).

But although Dartmoor's metal industry was of limited importance economically within the national context of production, as with all mining districts, it owed its origin and continued existence to a demand for materials and its changing character over time was due to capitalist mine adventurers responding to the fluctuations in demand. Dartmoor mining therefore had a place within, and was affected by 'world-system' economics .

3.2.2 Tin

Tin was Dartmoor's major metallic product and for this district it overshadows all the others, in terms of economic importance, output and duration, having been produced for many centuries prior to either copper or lead (Chapter 4, Table 4.1).

Tin has throughout its history been used mainly as a constituent of alloys, including bronze, where tin is the minor constituent to copper, and pewter, which in contrast has tin as the major constituent, with either lead (Pb) or copper (Cu) and bismuth (Bi) added to it. However, from the 18th to 20th centuries tin was also consumed by the tinplate industry in Britain, Europe and America. Other major demands for tin came from the far East, particularly in the late 18th century when a large proportion of the total output of British Tin was exported by the East India Company to China to manufacture tin foil used in religious ceremonies. Between 1789 and 1813, 18,559 tons of tin were shipped to China (Barton 1967, 28-9).

Pewter and Britannia metal

The term pewter includes several versions of this tin-based alloy but in strict terms applies only to an alloy with more than 50% tin, though in practice it may contain up to 99% tin (Hatcher & Barker 1974, 2). The earliest forms of pewter were a mix of tin and lead but by the medieval period small percentages of copper were being added. A further development in the late 16th century was the addition of bismuth and some pewterers probably added antimony, to produce a much harder version of the alloy (Hatcher & Barker 1974, 224-7).

Similar in constitution to pewter is Britannia metal, sometimes referred to as white metal, which was first produced in about 1770 and consisted of 90% tin alloyed with antimony. Despite this similarity, its differing manufacturing technique means that it is not usually referred to as pewter. Whereas pewter was essentially a cast product that is melted and poured into moulds and if necessary finished by turning or by hand finishing, Britannia metal was manufactured into thin sheets, then spun to form bowls, jugs, tankards and other table wares (Hatcher & Barker 1974, 287-8).

Although pewter artefacts are known from Egypt at around 1580-1350BC (Hatcher & Barker 1974, 6) it is from the Roman period that the first substantial evidence of its manufacture is available. The use of tin alloys is mentioned in Roman literature by Pliny the Elder (AD 23-79) and within Roman Britain at least 400 pewter vessels had been recorded by 1989 (Beagrie 1989, 170-1). There is a gap in the data regarding pewter in the Dark Ages but by the 10th and 11th centuries it was in occasional use for ecclesiastical vessels such as chalices. The alloy was not adopted for the production of domestic wares until the 14th century; thereafter pewter vessels in household accounts become more common and the production of pewter increased, reaching its zenith in the late 17th century but remaining static in the early 18th century (Hatcher & Barker 1974, 279). From 1740 onwards pewter household ware underwent a decline in popularity, as tin plate, silver plate and fine china became more fashionable, while an increase in the price of tin made pewter comparatively more expensive than tinplate, which used much less tin. The British pewter industry only avoided total collapse because of a rising demand for beer pots, following the introduction of commercial brewing from about 1780 (Hatcher & Barker 1974, 289).

Although the demand for pewter towards the end of the study period was nothing like as great as at the beginning, pewter was an important factor in consumer demand for tin throughout. But unlike tinplate (below) it is difficult to match consistently the demand for new pewter wares with a demand for white tin because pewter could, and usually was, recycled as pieces became unfashionable or worn out. At the end of the 18th century, the national stock of pewter was, according to one calculation, between 30,000 and 50,000 tons (Hatcher & Barker 1974, 292). As the demand for new pewter fell, this stock must have reached critical mass, reducing the demand for new stocks of material but it has proved impossible for economic historians to compile meaningful figures charting the vicissitudes of the pewter industry and collate it with those of tin production. Burt considered that by 1700, tin production was in stagnation because the market had become saturated and the pewter stock only needed topping up rather than being continuously replenished. The tin industry only revived following changing patterns of consumption as new, non-recoverable uses of tin were introduced later in the 18th century, at home and abroad (Burt 1995, 37).

Tinplate

Tinning of objects made from other metals, such as copper and iron is an ancient process believed to have origins in northern Europe during the Roman period (Gibbs 1950, 392). The process comprises the coating of pre-worked or cast objects with molten tin, either to prevent corrosion or to provide a decorative effect, which was a cheaper alternative to silver. The manufacture of pre-fabricated tinned iron plates from which objects could be fashioned came much later, probably in the 14th century (Minchinton 1957, 1), and by the 16th century Britain was among the countries importing small quantities of tinplate. By the early 17th century the continental trade in tinplate had increased, with port records revealing that 9,400 single and 20,00 double sheets were imported through London in the period 1618-19 (Jenkins

1995, 17); these plates were very often coated using tin originally exported from Britain.

In Britain however, the manufacture of the raw tinplates lagged behind that of Germany and France for much of this period. Although the precise date went unrecorded, it was the establishment of the first tinplate works at around 1720 in Pontypool by John Hanbury which is considered to mark the beginning of a tinplate manufacturing industry in Britain (Burt 1995, 38; Jenkins 1995, 24).

Although expansion was slow to begin with, after 1750 growth in tinplate manufacture in Britain increased rapidly until by the early 19th century, British manufacturers dominated the European trade and expanded still further from that date, replacing much of the imported material from Germany for the domestic markets, while also building an export market (Minchinton 1957, 15). Between 1805 and 1891 production increased from 4,000 tons to 586,000 tons (*Ibid* 1957, 28).

Some of the earlier uses of tinplate include pots pans and plates etc for the domestic market, but after 1859, from when the output doubled every decade thereafter, the main demand was coming from the canned food industry.

The researchers who compiled the history of pewter, paid great attention to the tin trade itself and sourcing of the raw material. For tinplate, Minchinton chose not to dwell on the procurement and demand for tin in his discussion; indeed he considered tinplate as a development of the iron and steel industry, stating only that the majority of the tin was sourced from Cornwall prior to 1860, but from then on supplies were obtained from Malaya and Australia (Minchinton 1957, 57).

Jenkins scarcely mentions the procurement of the raw material in his work on the South Wales tinplate industry, observing only that Cornwall was an important source of tin (Jenkins 1995, 8-10). But tinplate accounted for a large proportion in the usage of British tin, and after 1770 a doubling in the export of tin and tin products was largely due to the increased production of tinplate, which accounted for 50% of that growth by the 19th century, and from 1750 the growth of the British tin industry can be seen to be commensurate with that of tinplate over the next century (Burt 1995, 38).

3.2.3 Copper (Cu)

Copper is a useful metal in its pure, non-alloyed form but is also the main constituent of bronze and brass. Unlike tin, for which only tinplate and pewter created any measurable demand during the study period, the use of copper was much more diverse, including domestic, military, architectural, electrical and engineering uses. This was because of the broader range of properties the metal possesses, being easily cast, very hard wearing, resistant to corrosion and readily combining with other elements to form a range of alloys.

Bronze is formed by alloying copper with tin, though often modern bronzes include a small quantity of zinc. Once alloyed, the molten material has to be cast into moulds to form useful artefacts. It is particularly suitable for the casting of large and detailed objects such as architectural sculptures, bells, canon and ships propellers. The percentages of copper to tin vary but copper is always the major constituent, modern bronzes containing between 85 and 98%.

Bronze alloys were first produced in the early 2nd millennium BC when crude weapons were first cast from bronze in Europe. Early examples have been archaeologically excavated from Dartmoor dating from about 1600 BC (Pearce 1983, 90). Bronze bells were cast during Roman times and by the medieval period were among the major demands for this alloy, evident at local level by the highly successful bell founding industry at Exeter, for which there is archaeological and historical evidence from between the 12th and 18th centuries (Blaylock 2000, 4). The manufacture of bronze cannon during the 16th century created further demand for copper although economic historians have cast some doubt as to whether this demand was in fact as great as previously believed (Hammersley 1973, 21). By the beginning of the 18th century, the start date for this study, bronze was also in demand for domestic products such as kitchen utensils, pots, cauldrons and ornaments (Blaylock 2000, 22-7).

Brass is a mix of copper with zinc (Zn), though originally, before metallic zinc was available, calamine ($ZnCO_3$) was used. Although brass has its origins in the Roman period, a lack of known sources of calamine in Britain meant that no production of the alloy occurred here until the late 16th century following the discovery of calamine deposits in the Mendip area in 1566. Before this time all brass was imported. Even after this discovery the industry was slow to become established, with only one brass works of consequence being noted at Bristol in 1698, the British demand for brass being met mostly by imports (Day 1975, 32). The production of brass wire, to manufacture combs used in the textile industry, was of particular importance to brass production from the early 18th century (Burt 1995, 39).

Coinage has also accounted for a large portion of the national output of copper. In the last quarter of the 18th century, due to a lack of official smaller coin denomination, privately minted copper tokens had bee produced by industrialists. But in 1797 Mathew Boulton was granted exclusive right to mint copper coins for the British government; between 1797-9 he produced 1,818 tons of copper coinage and copper has formed an important component of the British currency ever since (Harris 2003, 89).

In 1761, the British Navy began experimenting with sheathing the underside of their warships with copper. This was found to be an effective means of protecting the timbers from barnacles and from infestations of shipworm, which was a persistent problem for ships operating in tropical climates. Once proved successful, the entire Royal Navy fleet was 'copper bottomed' in the two years following 1779

(Harris 1966, 554). The demand for copper generated by this practice, which was later adopted by merchant fleets and endured into the mid-19th century, was immense. Although met largely by Welsh copper from Parys Mountain, it accounted for a good proportion of the national copper output (Harris 2003, 45-50). A notable fact concerning copper bottoming is that the copper was mostly non-recoverable, suffering corrosion or becoming detached and lost, which served to deplete the national stock of the metal, helping to maintain demand.

A new demand for copper came in the first half on the 19th century following the industrial application of electricity, being the finest electrically conductive of the non-ferrous metals. Its use in electric motors and cables increased in importance as the 19th century progressed, to become the greatest consumer of copper in the 20th century (Prain 1975, 40-2).

Although limited information is available to associate the rise and fall of certain products with periods of copper production, no single product from copper can be identified as an agent of change or as causing an acceleration in production. However, the statistics compiled by Schmitz (1979, 6) demonstrate that the world production of copper between 1725, when the first reliable figures are available, and 1914 can be expressed as an exponential curve (Table 3.1). The average annual tonnage of 2,400 tonnes, between 1725-49, had been increased 16-fold a century later to 36 000 tonnes and by the early 20th century was nearly 900 000 tonnes. Unfortunately, the minute contributions of Dartmoor's copper mines are lost within this aggregate data, but against this backdrop Tables 3.2 and 3.3 show the annual production of British copper mines set against the price of the ore after 1771 from when the first data are available. The figures indicate that copper production was on an upward trending curve in the late 18th century, reaching an all time high in 1810 and, after another smaller rise in the 1850s, went into a sharp and terminal decline in the 1860s. Meanwhile the ore price, which had risen steadily since 1771, was artificially raised between 1792 and 1821, a possible outcome of the wars with France (1792-1815), to fall again and level out with another short-lived rise in the 1850s. World production of tin also rose steadily throughout this period, and British tin output reflects that rise with small fluctuations until the early 1860s when, a plateau of around £9 to £10 was reached, to fall irretrievably from 1895 onwards. World production however rose consistently over the whole period. Thus Dartmoor's copper and tin output, however small, need to be considered within the context of contemporary consumption and demand revealed by these figures.

TABLE 3.1

World Tin and Copper Production 1700 -1914 (after Schmitz 1979)

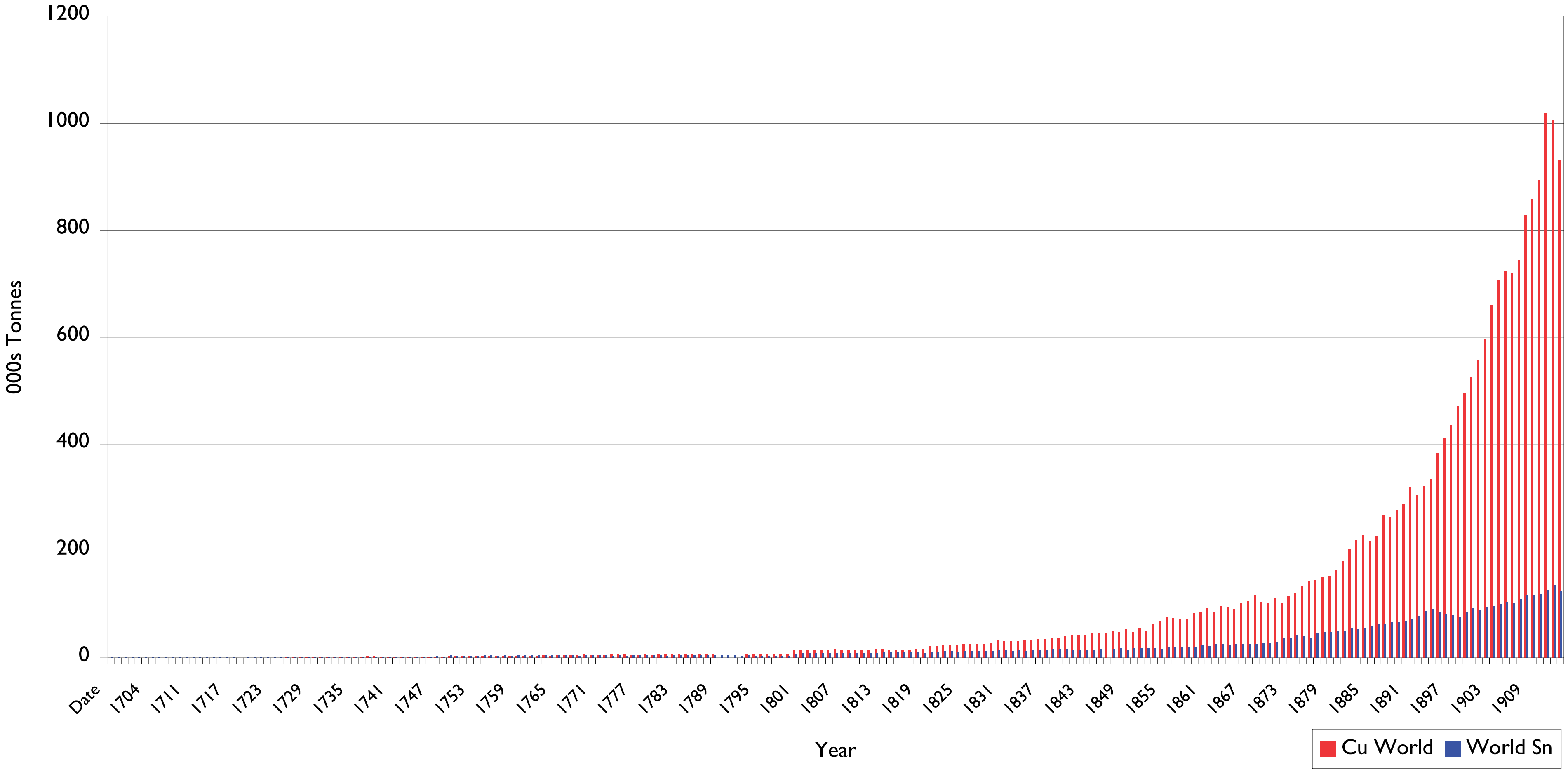


TABLE 3.2

British Tin and Copper Production 1700 - 1914 (after Schmitz, 1979)

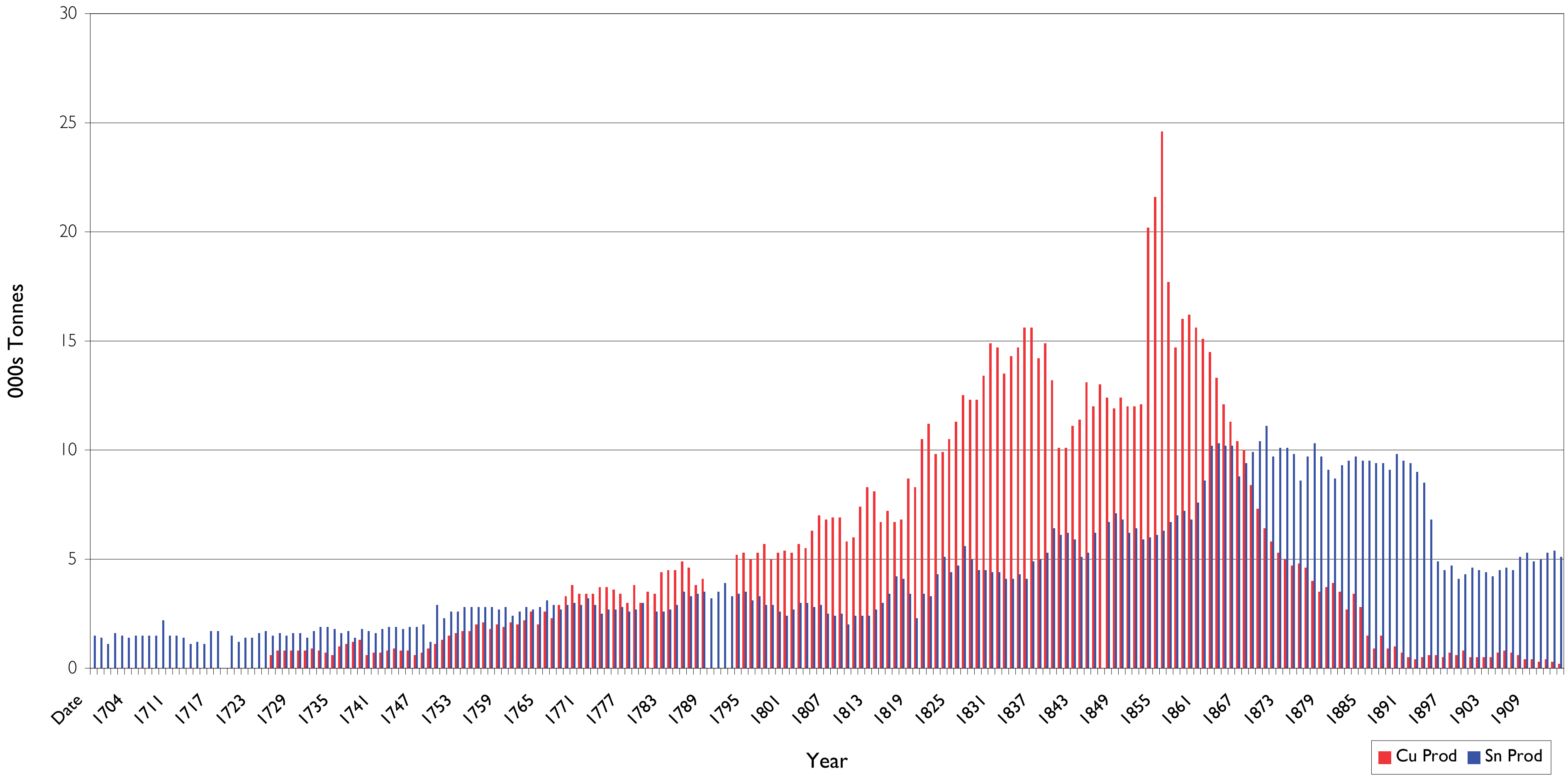
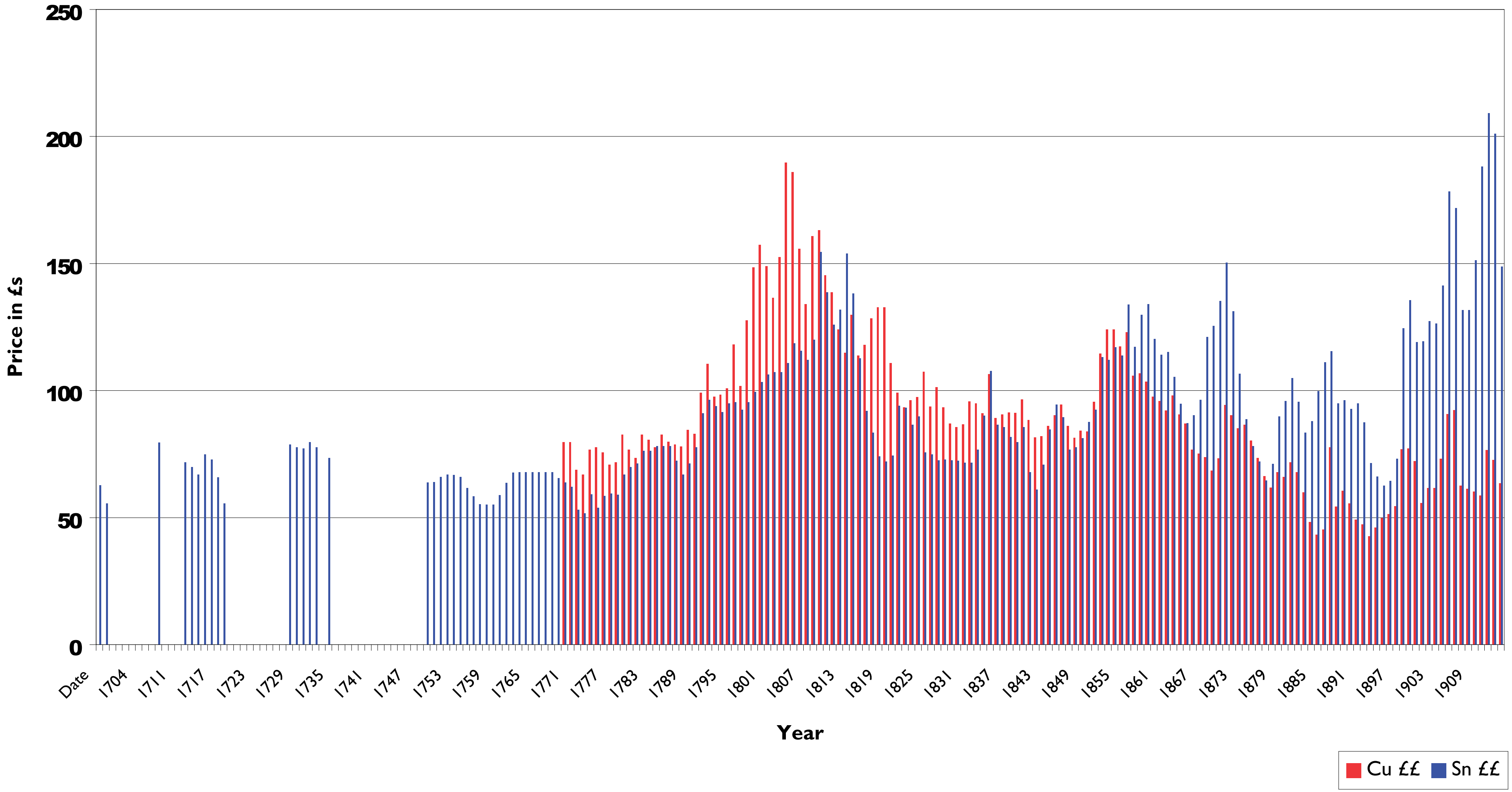


TABLE 3.3
Ore Prices for Copper and Tin 1700-1914 (after Schmitz 1979)



3.3 DISCUSSION

As the eastern outlier of the Devon and Cornwall metalliferous zone, the character of Dartmoor's geological assets were quite different to those of Cornwall, particularly the far west of the latter county. The excessive rise of the magma in Devon, caused by the processes of the Variscan Orogeny, and the exposed nature of the pluton itself resulted in considerable weathering. The natural erosion of the tin lodes that was incurred by this process bestowed Dartmoor and its hinterland with extensive deposits of alluvial tin, but conversely the tin lodes which remained *in situ* on the granite were the shallower, lower sections of the veins and of a generally lower grade. Within the metamorphic aureole the sulphide ores of copper and silver-lead, together with further veins of tin oxide, were found at greater depth but their presence is patchy and not as widespread as other districts in the peninsula and apart from the Mary Tavy district, the deposits tend to be small. As a mining district therefore, after the easily exploited alluvial tin deposits became depleted, Dartmoor would always be at the economic margins by comparison with the rich tin mining districts of Cornwall and the copper regions of Wales, Cornwall and Anglesey. This constraint must be borne in mind throughout the remainder of this discussion as it was fundamental to the outcomes of all economic decisions made by the adventures and to the character of the field evidence.

However, the demand for tin and copper metals in the 18th and 19th centuries rose exponentially, though for copper the poor market performance later in the 19th century signalled a decline in the profitability of British mines. In the case of tin, the falling consumption of pewter, which constituted the major demand for tin metal in the medieval and post-medieval period, was augmented by that of tinplate from the mid-18th century. Several forms of consumption may be identified as responsible for the increased demand for copper, rather than a single source, and the consumption of both metals continued to rise rapidly throughout the study period. Although the price of the ores may have fluctuated, the rising demand for the metals and the potential for profit during periods of high ore prices could have offset the disadvantages of working mines within this marginal district in the perception of those who invested in it, and must have been a relevant factor in the continuance of the Dartmoor mining industry.

These geological and economic issues provide a potent context in understanding the scale, output, technological choices and resulting material evidence for the landscape of mines in the Dartmoor district in the 18th – 20th century. They also offer important considerations in the analysis of the more localized historical dimension which must be examined next.

CHAPTER FOUR
HISTORICAL CONTEXT

4.1 TIN AND COPPER MINING ON DARTMOOR BEFORE AD1700

4.1.1 Tin

The extraction of tin is likely to have been occurring in Britain, specifically in the counties of Devon and Cornwall, since the prehistoric period. Although not scientifically proven, early origins for the industry in Cornwall have long been assumed on the basis of prehistoric and Romano-British artefacts recovered from 'old' tinworks of unspecified date, when they were reworked in the 19th and early 20th centuries (Penhallurick 1986, 173-224) but in Devon, archaeological evidence is even more fragmentary.

Tin ingots retrieved in 1992 from the seabed at the mouth of the River Erme in south Devon, one of southern Dartmoor's major rivers, may well have had origins in a Dartmoor tinwork then transported down the river to be loaded on to a trading ship near the estuary before it came to grief. The suggested date range for this find is between 500BC – AD600 (Fox 1996, 11, 22). Elsewhere in Devon, sediment analysis from samples taken from deposits in the alluvium of rivers whose sources are on Dartmoor, have produced material with C14 dates consistent with Roman or post-Roman activity (Thorndycraft 2004, 233); the precise location of any tinworks from this period or earlier, from where these sediments might have originated, is yet to be discovered

There is an oft-repeated but rather ambiguous passage in *Diodorus Ciculus* (Book V, 22) written in the mid-1st century BC, which tells of a trade in Westcountry tin in the late Iron Age, and an island by the name of Ictis off the coast of Britain from where the tin was traded. Although anecdotal, the descriptions of tin being wrought from veins do seem authentic and there is no reason why this account should not be true; the island of Ictis is usually identified as that of St Michael's Mount (Finberg 1949, 155). A less well substantiated tradition that British tin was traded with the Phoenicians has endured for several centuries in Westcountry historical literature but is no longer accepted as accurate (Penhallurick 1986, 123-31).

Despite a small corpus of archaeological material testifying to the working of tin in Cornwall during the Dark Ages (Penhallurick 1986, 237-44), and much inference drawn from various documentary sources that suggests the same (Lewis 1908, 33-4), in Devon concrete evidence for tinworking comes as late as 1156, when taxes gathered from the owners of tinworks are mentioned in the Pipe Roll of that year (Lewis 1908, 34). This is the first specific documentary evidence for tinworking in Britain. At that time tin production was low and apparently only Devon was producing tin, as Cornwall is not mentioned in the statistics in the first four decades that they were recorded (Lewis 1908, 34). The tin industry was clearly gaining momentum by the late 12th century because in 1198, in both counties, the working of tin began to be regulated and a stannary warden was appointed by the crown; standard weights for finished tin were also introduced as were additional taxes (Pennington 1973, 14). The first 'stannary' charter was issued by King John in 1201 (*Ibid,* 15) and this confirmed the customary privilege of 'tin bounding' which allowed the tinners to search for tin wherever they please and divert water supplies as they needed them (see below). Penhallurick has suggested that such freedoms could only have developed in a sparsely populated landscape, and may therefore have had origins in the 'Dark Ages' (Penhallurick 1986, 237). However, in Devon, archaeological and historical evidence have so far failed to positively identify any individual tinwork prior to 1239, when 'la Dryworke', believed to be a streamwork at Dry Lake, was recorded in the first perambulation of Dartmoor Forest (Rowe 1896, 290).

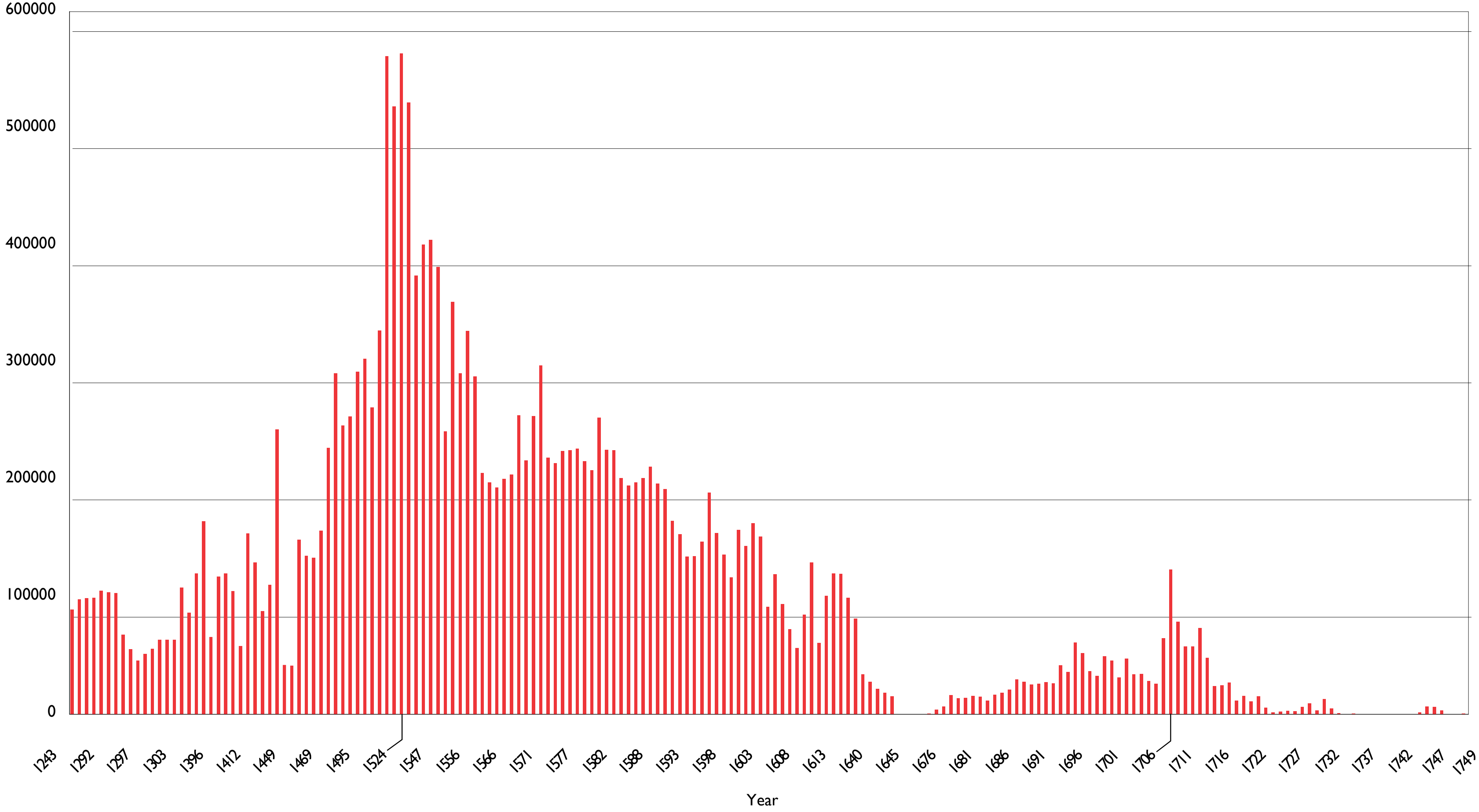
The 1201 charter also removed the tinners from common law and henceforward all matters of justice concerning tinners and the tin industry came under the jurisdiction of the Lord Warden of the Stannaries (Lewis 1908, 36), the first of whom was William de Wrotham appointed in 1197 (Pennington 1973, 223). The stannaries were the several districts which made up the tin mining region of Devon and Cornwall from which the industry was presided over and administered. After a charter of 1305, Devon and Cornwall were dealt with separately and by 1328 Devon had four stannaries, centred on the towns of Ashburton, Tavistock Plympton and Chagford (Greeves 1987, 147). Each district elected a number of persons (jurates) who had associations with the tin industry to represent them at the stannary courts or parliaments, where all legislative affairs connected with the tin industry were dealt with.

Despite the freedoms enjoyed by the tinners, their industry was very tightly regulated with regard to taxation or 'toll' at the point of sale of the finished product. Smelted or 'white' tin could only be sold at stannary towns on certain days known as a 'coinage' where sales were recorded and the toll paid (Finberg 1949, 171). It is thanks to the record-keeping by the stannary officials that detailed figures survive regarding tin production for Devon from 1243 to 1750 (Table 4.1). These statistics show that, from the 12th to the early 16th century, tin production in Devon was on the rise and reached a peak of 470 thousandweight (251.7 tons) of white tin in 1524. Thereafter the decline was as steep as the rise had been and output had fallen to zero by the time of the English Civil War (1642-1648), recovering briefly in the late 17th and early 18th century, but to be in decline again by 1750 when output for Devon and Cornwall were combined from that date forward (Lewis 1908, 257).

Detailed studies of the stannaries, and their relevance to the medieval and post-medieval industry, have been discussed in Chapter 1. Although the relevance of much of this work lies beyond the scope of the present study, the importance of the stannaries as a cohesive force in perpetuating the laws and ancient customs of the tin industry resounded well into the study period, providing a continuity of tradition which lasted nearly 600 years. Some aspects of these traditions are explored in Chapter 5.

TABLE 4.1

Annual Tin Production Figures for Devon 1243-1749 in pounds weight (after Lewis 1908)



Although documentation for the Devon tin industry is available from the 12th to 14th centuries, it is not until the 15th century that historical sources start to be of use as a means of interpreting elements of the Dartmoor landscape, when specific references to tinworks, processing mills and smelting sites become more frequent (see Greeves 1981). Over 834 individual tinworks are documented between 1450 and 1750, the majority of these works were alluvial streamworks, not lode workings and certainly not mines.

4.1.2 Tin Streamworks

The technique of tin streamworking is likely to have ancient origins at the very commencement of tin exploitation in Devon and Cornwall, possibly during the post-Roman or early medieval period or even earlier. Although this study is concerned with the hard-rock mining of metallic lodes, the influence of centuries of tin streamworking on the later mining industry of the 18th - 20th centuries cannot be avoided, indeed it will be argued in Chapter 5 that the profound effect of past mineral exploitation on the landscape, of all types including tin streaming, had a lasting influence on the traditions of mining in this place.

Streamworking involved a completely different form of mineralogical deposit known as placers (Chapter 3), and a different means to exploit it. The most detailed archaeological study of streamworks in both Devon and Cornwall is by Gerrard who defined a streamwork as:

> *exploiting tin that had become detached from the parent lode and subjected to varying amounts of weathering and transport before coming to rest in the tin ground*
>
> (Gerrard 2000, 60)

The 'tin ground' often lay within river or stream valleys, or on hill slopes. To extract this alluvial tin it was necessary to separate the ore from the waste materials that were deposited alongside it, known collectively as 'gangue'. This was achieved by taking advantage of the disparity in the specific gravity of the cassiterite, which was between 6.8 and 7.1, compared with the gangue material of between 2.5 and 2.9 (Gerrard 2000, 60). When introduced into flowing water the two could, with the application of certain techniques, become separated. The field remains of streamworks reflect this operation and comprise many hectares of disturbed ground containing water channels and dumps of waste material. Evidence for streamworks is found in most areas of Dartmoor, particularly the upland and especially in the river valleys, where the alluvial deposits are most common. A recent study revealed that within the Plym valley, the alluvium of every upland tributary of the River Plym had been worked by streamworking, covering over 110ha (Newman 2006a, 130). A similar story is revealed for the rest of Dartmoor on aerial photo plots such as those published by Butler (1994).

It will be argued below (Chapter 7) that by 1700 lode workings, or mines, were of greater economic importance than streamworks on Dartmoor but despite this there is plenty of evidence to suggest that

Fig 4.1 Aerial view of Dick's Pits tin streamworks at the head of Doetor Brook showing the extent of disturbance cuased by streamworking in a typical upland valley. (NMR 24680/023)

streamworks continued to be relevant in Devon and small-scale streaming of tin certainly continued well into the 19th century. In 1808, for example, Charles Vancouver reported:

> *Some old stream-works have lately been renewed in the parish of Plympton St Mary's, and in such a manner as gives great hope of success to the present proprietors.*
>
> (Vancouver 1808, 67)

And a little later, Mrs A E Bray claimed:

> *The stream-works, though less productive than the mines, are still, in many instances, a source of profit to the adventurer*
>
> (Bray 1832, 146)

The tone of these last two comments strongly suggest that both writers were referring to the reworking of old streamworks and examples continued to be recorded. In 1863 for example, 12-15 men were occupied with this activity in the Doe Brook and West Okement valleys (Greeves 2003a, 24) but it is very unlikely that any new works were begun in the 19th century.

By 1839, De la Beche, in his seminal work on geology and mining, wrote that:

> *Though streaming for tin has formerly been carried on extensively upon Dartmoor and in the valleys rising from it, stream-works are not now found in Devon*
> (De La Beche 1839, 647).

Of all the extractive metallurgy that occurred on Dartmoor, streamworking has had the most enduring and visually striking effect on the landscape (Fig 4.1). It was amidst this backdrop of past upheaval that the mining industry of the 18th and 19th centuries was cast; the more modest remains of the later efforts often standing amidst the streamworking remains, which served perhaps as a reminder to the later miners of the potential of the place.

After about AD1500, 'beamworks' have a presence in the documentary record, a term which refers to opencast lode workings (Greeves 2004, 9-11), and from then onwards the working of tin lodes increased in importance as underground techniques also developed (Chapter 7) and by 1700, at the commencement of this study, tin mining was well established, though the industry had seen its best days and, judging by the tin production figures, was no longer prosperous. In 1610 William Camden had compared Devon with Cornwall and claimed the county was 'no lesse enriched with tin mines, especially Westward' (Camden 1610). By 1641, another writer, borrowing heavily from Camden, had corrupted this sentence somewhat whereby Devon was: 'enriched with inexhaustible mines of tinne' (Heylin 1641). This may have been the perception of distant historians, but in 1641 Devon's annual tin production was only 15 thousand weight, the lowest figure since records began (Table 4.1) and although rallying occasionally over the next 70 years or so, tin production in this county would never regain the significance it had in the 16th century when production from streamworks was at its zenith.

4.1.3 Copper

In Britain and Ireland, radiocarbon dates confirm that mining for copper was occurring by the late 3rd millennium BC at Parys Mountain on Anglesey, Cymystwyth in Ceredigion and Ross Island County Kerry (Ixer & Budd, 1998, Table 1). Mining for copper in the south-west of England during prehistoric and Roman times must be considered a possibility (see Craddock 1996) but no evidence has thus far confirmed this. It is in the medieval period that the first, somewhat fragmentary, evidence is available for the working of copper in the south-west peninsula.

The origins of medieval copper mining in Devon are elusive, far less certain than those of tin, and the search for copper does not share the same remote history and traditions. The subject has vexed Devon and Cornwall's historians since the late 18th century (Taylor 1799; Carne 1828, 35-85; G. Borlase 1832, 446-9), and the number of primary sources available has increased hardly at all since that time. In 1799, John Taylor the renowned mine entrepreneur, claimed that:

Copper.. was not an object attended to, till a comparatively late date, by the Cornish miners: even in tin mines, which as they deepened produced copper, as is often the case, and where they needed to raise this ore, it was thrown by as of no value, going by the name of poder
(Taylor 1799, 363).

In 1778, writing only of Cornwall, William Pryce firmly asserted that:

'.. mining for Copper only commenced with the present century; the little that had been raised before, being adventitious, and accidentally met with in pursuit of Tin'
(Pryce 1778, xi)

Twenty years earlier in 1759, also on the subject of Cornish copper, William Borlase, paints a similar picture, claiming that the exploitation of this metal had only been profitable within the past 60 years, and observing:

so little does discovery [of copper] signify, unless it be pursued with application, and knowledge how to make the proper advantage of it
(Borlase 1758, 196)

Implicit in this statement is that a knowledge of its presence was not matched by a willingness or ability to exploit the metal by Cornish adventurers. It is likely that similar attitudes might have prevailed in Devon, though without evidence this cannot be claimed with certainty.

Further back, in 1601, Richard Carew claimed that copper could be found in Cornwall 'but with no gain to its searchers' although at least one mine was shipping ore to south Wales at that time (Carew 1602, C2).

Fragmentary medieval documentation for copper mining in Devon does exist however, and the earliest occurrence was in 1346 when, on 22nd February, one Nicholas de Welliford was granted the role of the king's copper mine at North Molton though it was reported that he had lost heavily (Dixon 1997, 42-3). In the following decade a patent was granted to John Balancer and Walter Goldbeter by Edward III in 1359, for his mines of gold, silver and 'copper' in Devon (Donald 1955, 96), although the nature and location of any associated mining activity is not known.

Aside from the lack of documentary evidence, there are reasons to be doubtful that an earnest search for this metal in England commenced until the late 16th century, during the reign of Elizabeth 1st. Donald concluded that the necessary expertise to exploit copper was lacking in Britain before German mine entrepreneurs imported skilled miners to this country in the 1560s led by Daniel Hochstetter, who first came to England in 1563 (Donald 1955, 37). In 1568 Hochstetter's operation was formalized as the Society of Mines Royal, a monopoly backed by the crown with exclusive rights, or Letters Patent, to mine in certain counties. Together with The Society of the Mineral and Battery Works, which had similar privileges but in different counties and in Ireland, these were the first joint-stock companies to be formed in Britain (Hammersley 1973, 3). Although the majority of effort by Mines Royal focused on the copper mines of Cumbria around Keswick, Hochstetter also commenced mining in Cornwall in 1564 in the Perranporth area though unsuccessfully (Buckley 2005, 82). Twenty years later another German, Ulrich Frosse, re-commenced the Cornish copper operation with only slightly improved success, but this too was not an enduring venture, terminating in 1584 (Donald 1955, 300-42).

There is no record of specific copper workings in Devon during this period, though scraps of information are available. Firstly, Devon is one of the four counties that Hochstetter and his associates were granted a warrant to explore in 1563 (Donald 1955, 103). It is also known that in May 1583 the Mines Royal let their rights to Devon for a term of fifteen years to Adryan Gilbert of Devon and John Dee of Surrey, who paid £20 the first year and £50 for subsequent years. Gilbert is known to have been an active mining entrepreneur; he was a jurate representing the stannary of Ashburton (Greeves 1987 157), so was clearly involved in the Devon tin industry; in 1582 he was the tenant of Ausewell Wood (Phillpotts 2003, 6), where early 17th-century iron workings and undated copper mines exist (Newman 1998; 2004a) – he also had interest in the Coombe Martin Copper Mines in north Devon (*DCNQ* **7**, 54-7). Dee, an academic, was an associate of Gilbert in other ventures but is not known to have been involved in other Devon mining enterprises. Only six years later, Thomas Smith took on the Devon lease (Hammersley 1973, 6). In 1595 a minor dispute is recorded over the rental payable to The Society of Mines Royal for copper mines, including those in Devon, and they are mentioned again two years later in 1597 when the figure of £20 is said to be owed for the Devon mines (Donald 1955, 357-8). Regrettably, unlike the records for Mines Royal's operation in Keswick, Cornwall and Neath (South Wales, where Cornish copper was smelted), there are no detailed records of a Devonshire operation, so it is not possible to state if or where copper mining took place in Devon during the tenure of the Society of Mines Royal.

Hammersley (1973, 1-31) has questioned many of the assumptions which formerly surrounded the Society of Mines Royal. Firstly, he claims that the demand for copper in the Elizabethan period was probably not as great as formerly believed, particularly for ordnance purposes, i.e. cannon manufacture. Also, that the cost of producing ore in England, which were not of fine quality, was greater than on the continent, especially fuel and labour costs. The moderate success of the Keswick mines may be solely due to the 'exceptional technical and mercantile competence of the Hochstetter family' at a time when low demand and high costs caused all other attempts at mining copper in England to fail (Hammersley 1973, 27).

The significance of the Society of Mines Royal is also questionable, as their output and influence may have been far less than previously believed (Burt 1991, 253). What economic historians have concluded is that it was the demand for and economics of copper production that held back the development of the industry, not the lack of skills amongst British miners and smelters, or the effect of restrictive practices imposed by the Society of Mines Royal exercising a monopoly.

The involvement of gentry figures like Gilbert, Dee and Smith in early attempts at copper mining and other metallurgical enterprises in Devon is highly significant, despite their apparent lack of success. Their activities are indicative of the very different type of industrial organization which was necessary for the exploitation of hard-rock mines and the need for private capital and experimentation. This contrasts with the less capitalized tin industry which was in that period still thriving on the strength of the placer deposits or streamworks. These issues are discussed further in Chapter 5.

Returning to Devon, Hamilton Jenkin (1974, 47) and Harris (1968, 60) have both claimed the existence of at least one Elizabethan copper mine on the edge of Dartmoor which comes from the name 'Virtuous Lady', given to a copper mine in Buckland Monachorum parish; this mine is documented from the early 18th century (Brooke 2001, 13) but is said in tradition to have been named in honour of Queen Elizabeth (r.1558-1603), and had origins therefore contemporary with her reign. This may be a Red Herring unwittingly provided by these authors for which there is no evidence, as it is equally, if not more likely to have been named after Queen Anne (r.1702-1714), if named after a monarch, and the mine was certainly in operation during Anne's reign.

Another possible glimpse into pre-17th-century Devon copper mining comes from a memoranda of William Carnsew, who mentions some rich copper workings beside the Tamar in 1580, which Hamilton Jenkin suspects may be on the Devon side of the river near Gunnislake Bridge, though the full extent and precise location of this activity is not known (Hamilton Jenkin 1974, 17-18).

Of the early 17th- century Devonshire historians, Westcote writing in 1630, refers only to copper mines existing at Newton Ferrers (Oliver 1845, 65) and Risdon, whose Survey of Devon was completed in the same year, mentions tin, lead, iron, silver and 'other metals' as the metallic ores being wrought in the early 17th century. Copper is not specifically mentioned though it could be included in the 'other metals' which perhaps implies its lack of significance in Devon at that time (Risdon 1811, 8).

Risdon's Survey of Devon, although covering the period 1605-1630, was re-published in 1810, and it was John Taylor who wrote the introduction to this edition (Risdon 1811, i - xxxvi). He was clearly in possession of more information than when he last discussed the subject (above, 1799) and wrote that 'Evident traces of ancient works have lately been discovered on a copper lode at Crowndale, near Tavistock'. Again, it is possible only to speculate as to the precise nature of this evidence and from what date it may have its origins.

Webster (1671, 245) fails to mention Devon or Cornwall in relation to copper, referring only to the Cumbrian mines, which were by that time out of use, although his contemporary, Sir John Pettus, states that:

> *Copper Mines containing some Gold and Silver are in Cornwall, Devonshire, Somersetshire, Gloucestershire….*
>
> (Pettus 1670, 6)

It was not until the last two decades of the 17th century, and the early 18th century that a more profitable and enduring copper industry is likely to have become established in south-west England, specifically in Cornwall when over 1000 tons of ore was exported to the Bristol smelters and named mines such as those on Tolgus Downs are first recorded (Barton 1978, 12). Several factors may be identified to account for this growth in Cornwall, and by implication the same model could, to a lesser extent, apply to the few Devon copper mines which are known to have been in existence by the early 18th century (Table 6.2). The abolition of the Mines Royal monopoly in parliamentary acts of 1689 and 1693, which freed owners of ore-bearing land to exploit them for profit, has been cited as the elimination of one major barrier (Barton 1978, 11-12). The significance of this act however remains debatable in the light of the work of Hammersley (1973, 1-31) and others who suggest that the existence of Mines Royal had never been a barrier to those wishing to explore for copper in England. Secondly, the growth of joint stock adventures enabled the large investment of capital needed to explore for minerals and set up working mines, to be shared by investors or 'adventurers' (Buckley 2005, 84).

Both factors were contemporary with a period of rising consumption of materials (Chapter 3). Parallel with this was the fact that coal was being introduced to smelt the ore, which in Britain was cheaper and more abundant than the charcoal used previously, enabling British copper to compete with that of Sweden, the principal European producer at that time, where smelting depended on charcoal (Barton 1978, 11). The gradual introduction of gunpowder as a means of blasting the rock also enabled greater progress in the mines, where previously miners had to rely on fire-setting or hand tools alone to break rock. According to Earl, gunpowder was first used in a mining context in Chemnitz in Hungary in *c*.1600. It was introduced to Britain in 1638 at Ecton in Staffordshire and the method was being adopted in the Westcountry mines by the 1690s (Earl 1978, 15). The process of adoption could have been slow due to the added expense and the need for skilled miners to adapt to a more hazardous technique, which probably required greater remuneration (Burt 1991, 258).

These historical debates are as yet untested archaeologically, for either the period leading up to the commencement of the study period (1700) or within the study period itself but clearly have great relevance to the topic of capitalist involvement and the impact thereof on the mining industry, a theme which is further examined in Chapter 5. Historical material has not supplied definitive information as to the origins of copper mining in Devon, and it may be that archaeological evidence will at sometime in the future provide more certainty. However, despite any gaps in the early historical account for tin and copper mining of Dartmoor, the working of metalliferous lodes using underground mining techniques was certainly well established by 1700; traditions embedded in the organization of the tin industry were strong enough to be influential to future developments and early signs of private capitalism and the joint-stock company are evident in the attempts to establish the mining of copper.

4.2 HISTORY, STATISTICS AND PERCEPTION POST-1700

The following is a historically-based reconstruction of mining for copper and tin on Dartmoor between 1700 and *c.*1914. It includes extracts from contemporary writers that provide testimony, in some cases unwittingly, as to how the scale and importance of Dartmoor's mining industry in that period was perceived and reported on by those who observed and recorded it. Where named mines referred to in the documentary record have field remains that have been recorded as part of this research, they appear under the same (primary) name in chapters 6-9 and accompanying tables. However, no correlations should be made between dates mentioned below and specific pieces of field evidence.

4.2.1 The 18th century

Unlike Cornwall, where copper mines such as those on the Tolgus Downs are recorded in production by 1706 (Barton 1961, 12), there is a shortage of documentation for copper mining in the same period in Devon. However, it is probably safe to assume that although likely to have been on a much less developed scale, some copper exploration of the Dartmoor border country had begun by 1700 or very soon after. John Taylor states for example, that a Mr Moore was employed in searching for copper in Mary Tavy and adjoining parishes, early in the 18th century (Risdon 1811, xix).

Some of the earliest references to specific copper mines in Devon come from the journal of Heinrich

Named by Kalmeter	Ore	Later or alternative names	Within study area	Date if stated
Ausewell Wood	Cu		✓	
Black Down	Pb	Probably Wheal Betsy	✓	
Buckfastleigh	Cu	Possibly Brookwood	✓	
Buddleybeer	Sn	Wheal Jewell	✓	
Forrest Hill	Sn	Furzehill	✓	
Hawk's Well	Sn			
Hocklake	Cu			
Impham	Cu			
Marquis	Cu	Bedford United		1707
Piggiford	Sn			
Tavistock			✓	1712
Virtuous Lady	Cu		✓	
Whiddon Down	Sn		✓	
William and Mary	Cu			1718

Table 4.2 Devon Mines recorded by Heinrich Kalmeter in 1724 (source Brooke 2001)

Kalmeter, a Swedish national who toured Britain in 1724-5, visiting mines and other industrial processes and noting what he saw (Brooke 2001). Kalmeter described in detail seven copper mines in Devon and his writings implied that copper was very much the future of mining in this district while tin was in the doldrums.

Of the copper mines mentioned, he informs us that 'Marquis' (i.e. Bedford United) was started 'seventeen years ago' (i.e. in 1707). 'Tavistock' was 'worked for four or five years but has been idle these seven years' so would have origins at around 1712. 'William and Mary mine' was six years old (1718), while 'Ausewell', 'Virtuous Lady', 'Hocklake' and 'Impham' were so described as to suggest they were well established. 'Buckfastleigh' mine, also disused, is described as 'old and 40 fathoms deep' and had been abandoned the previous Whitsun. Such specific information regarding individual Dartmoor copper mines is scarce in the 18th century, at least until the 1790s, and probably indicative of very little activity in the intervening period.

Tin mining on Dartmoor in the early 18th century was in a recession for which the tin production figures of the preceding half century recorded by the Stannaries, offer a context (Table 4.1). Following the rise and fall of tin production in the later middle ages, decline was rapid during the 1640s, when Heylin (above) published his optimistic statement. Then, apparent stagnation of the industry in the Civil War was followed by a steady, though very modest, recovery in the 1670s and 80s, peaking again in 1706 with a recorded output of 123,636lbs (55 tons), a somewhat atypical spike on the graph. This figure had declined to less than 9,000 lbs (4 tons) per annum throughout the 1720s. The fall continued until 1749, after which figures for Devon were combined with those of Cornwall (Lewis 1908, 255-6). Statistically, Devon's contribution is uncertain thereafter until Robert Hunt began preparing mineral statistics specific to individual mines from 1853 (Burt et al 1984). In contrast to Devon's poor and somewhat sporadic figures, British tin production was rising exponentially in the 18th century, from an average of 1.8 thousand tons (1,830 tonnes) annually in the period 1700-24, of which Devon's contribution was a per annum average of 15 tons (15.24 tonnes or less than 1%), to 4.3 thousand tons (4,373 tonnes) in the period 1750-74 (Schmitz 1979, 6); clearly the majority of this tin was from Cornish sources.

Contemporary observers offered gloomy commentaries on the early 18th-century tin industry in Devon. Kalmeter for example, in contrast to his account of copper, was quite downbeat. Describing the Tavistock district, he claimed that: 'the tin works …. have all closed down or come to nothing'. One mine only was producing tin, three miles from Tavistock in Whitchurch parish, though it is difficult to establish which this was from the description given. He also lists several recent failures, including Forest Hill (Furzehill), Piggiford and Hawks Well (Brooke 2001, 11). The only other tin mine mentioned by Kalmeter was Whiddon tin mine in the Ashburton district; it had been an 'old work, which for a while stood idle' but had been 'taken up again' (*Ibid,* 47). However, it appears that Kalmeter's tour did not penetrate the upland districts of the moor, and the mines he did visit were all close to the well-used roads of the time. This is not surprising as the trans-Dartmoor route was not built until late in the 18th century and few travellers were able to visit the high moors until the 1790s (Milton 2006, 32); it is also possible that poor access to the upland may have acted as a deterrent to mine adventurers and mines therefore just did not exist on the high moors during this period.

In 1710, one of the Jurates who attended the tinners' Great Court of that year was clearly not overly impressed with Devon's position at that time:

> *You must note that this County was antiently the great Tin County; but as the Tin-Works grew deep and wrought out, so by degrees 'tis got into Cornwall, where they now as much out-do this county as this formerly did that*
>
> (*Daily Courant* 09-Jun-1710)

Ten years later, a similar statement was published in Cox's *Magna Britannia,* in which the author claims:

> *In King John's Days, there were Tin-Mines found and wrought in this Forest [of Dartmoor], that have long been discontinued.*
>
> (Cox 1720-31, 471)

Documentary fragments however, attest to sporadic activity; at Bottle Hill for example where a lease to 'delve and search for tin within the tinwork or mine…' was granted in 1715 (Hamilton Jenkin 1974, 125).

In 1753-5, R R Angerstein, another Swede on a tour of England, visited the Westcountry. Although writing a great deal about Cornish mining, he dwelt little on Devon's mines and what he did write concerned only the past, with no suggestion that he witnessed any current activity:

> *On Dartmoor there are, even now, substantial remains to be seen of the works of the ancients. These are thought to have been stream-works, as there are no shafts or proper mines*
>
> (Berg & Berg 2001, 115)

> *This gives one reason to believe that the old tin mines worked on Dartmoor in ancient times may have been destroyed … and hidden from our eyes by the changes brought about over the years*
>
> (Ibid, 115)

Theophilus Botanista when referring to the state of the Devon tin trade:

> *…Cornwall has almost the whole trade; for not withstanding there are some works here [Devon], the advantages are very trivial and insignificant, unless in two or three very lately opened*
>
> (Botanista 1757, 113)

T G Smollett's brief description of Devon in 1768-9 also included the words: 'Formerly there was a great deal of tin dug out of it, tho' now very little' (Smollett 1769, 286). It seems almost certain that Devon's active streamworks had become so inconspicuous that most commentators considered the industry to be either completely finished or working at an extremely low level, and that exploring for tin in mines had not developed to a level of significance either, which corroborates the Stannary production figures. It is notable that the latter three of these writers make no mention of copper or silver-lead mining in Devon either, which provides a strong hint as to a general lack of all mining activity in the mid 18th century.

In 1765 the first map of Devon was published by Benjamin Donn (Ravenhill 1965). Only six mines are depicted for the whole county, five are on or around Dartmoor of which only three are named; these are 'Widdon Smelting House Tin and Copper Mine', 'Wheal Hazel' (i.e. Ausewell Wood), and 'Budlake' (i.e.Wheal Jewell, referred to as Buddleybeer by Kalmeter). Two other sites marked simply 'Tin Mine' and 'Copper Mine' can be assumed from their location to be Crowndale and Virtuous Lady.

It is not known how Donn selected mines for depiction on his map. Perhaps those shown were the most productive, or possibly the only operational mines at that time, or they may have been the largest employers within this industry, but they may not even have been in work and could have been notable for historical or other reasons. Ausewell is a curious choice for inclusion because, although known to have been successful earlier in the 18th century, in 1763 when Donn was surveying his map, the mine is known to have lain idle for some years (*SYM* 30.07.1763). Whiddon was active in the late 1750s (Amery 1925, 43-52) and may still have been so in 1763. Of these five, all except Crowndale were mentioned by Kalmeter 40 years earlier as working mines. The depiction of these mines on a map however, does not provide definite evidence that any were actually working at that date. Again there is no reference to mines on the uplands but with this source we can at least be certain that Donn visited the area to survey the topography.

Despite Devon's poor tin returns leading up to 1750, there is primary documentary evidence for tin mines being worked mid-century at Vitifer in 1750 (Hemery 1983, 614), which does not feature on Donn's map, and Widdon, which was previously mentioned by both Kalmeter and Donn; it is known that a group of adventurers were active at the latter mine in 1757 (Amery 1925, 43-52). Another mine for which a lease is 'said to have been granted' was Wheal Lopez in 1760 (Hamilton Jenkin 1974, 117). There is also evidence of tin 'bounds' being pitched at places known to have later become mines, at Keator near Vitifer for example, pitched in 1754, Brownshill in 1758 and Huntingdon in 1759 (Burnard 1891, 85-112). Also near Vitifer, Challacombe was pitched in 1754 and East Birch Torr in 1757 (Brown 2000, 95).

The practice of tin bounding was an ancient customary right possessed by the Devon and Cornwall tinners that became enshrined in stannary law in the charter of 1201 (Pennington 1973, 74). In Devon, where the rights differed slightly to those of Cornwall, bounding allowed tinners to search for tin wherever they wished, regardless of the landowner's rights. This extension of these privileges was not enjoyed by their Cornish neighbours, who required owners of enclosed land to allow the land to be worked before bounding could take place. Individual adventurers had shares or 'doles' in each tinwork and once claimed or 'pitched', these bounds could be renewed whether they were being worked or not. In 1724 Kalmeter, who considered Devon tin working to be in a state of deep recession at the time of his visit, recorded how 'bounders, or those who have shares in tinworks' renewed their bounds once a year (Brooke 2001, 11). However, the fact that a tinwork was mentioned in this context at a certain date, does not indicate that it was in work; it is recorded in Cornwall, that bounds were frequently pitched and renewed without any work ever taking place and the bounders were simply maintaining their claim (Hamilton Jenkin 1972, 34-5). In 1769, George Lord Edgecombe commissioned William Andrew to 'enquire and renew' his shares in a list of 95 Devon tinworks in which he claimed ownership (CRO ME 2794). Although several can be identified as lode or 'beam' works, of which some were later to be developed into mines, such as 'Courrbeam als Quirrbeam' (Curbeam), 'Keagles borrough' (Keaglesborough), 'Hawlecoombe or Owlacombe' and 'Huntinton Beam' (Huntingdon), many where location is identifiable are streamworks including 'Deadlake' (SX565785), 'Meavyhead in the Forest', (SX583733), 'Brightswork (Brisworthy) Burrows' (SX563645). Unfortunately there is no proof that any of these tinworks were active in 1769 or that some ever became active again; it is likely that Edgecombe was ensuring his interests should mining or streaming become viable on these sites in the future.

There is also evidence that at least two tin smelting mills were operational on Dartmoor at Plympton and Sheepstor between 1719 and about 1751 (Greeves 1996, 84) and in 1757 a tin smelting mill and burning house was being planned at Whiddon, Ashburton, associated with the mine of that name (CRO R/4998). Black (i.e.unsmelted) tin must have been available to make these mills viable.

The stannaries in the 18th century were still active despite the vicissitudes of the industry and at least four Great Courts were held, though it is possible that others went unrecorded, or have so far eluded researchers. These were in 1703 (Greeves 1987, 159) and 1710 (*Daily Courant* 09.06.1710) during an active period, but another may have been held in 1749 (Bray 1879, 107), during a period of serious slump. The last Devon Great Court was held in 1786 when a minor upturn in the fortunes of Devon tin was imminent (Greeves 1987, 160-1). However, John Taylor, writing in 1799, considered that unlike Cornwall where the laws had been kept up to date, in Devon where 'mining has for a long while slumbered, the laws continue in their original crude state'. If, as seemed likely to Taylor, there was to be a revival, the laws would 'probably undergo some revision' (Taylor 1799, 362).

The fact that the Stannaries Courts still had business to discuss tends to indicate that tin was not considered completely moribund in Devon. However, it would seem that for much of the 18th century, those observing from outside viewed Devon's tin 'industry' as of little or no significance, while it is clear that activity continued, albeit on a limited scale. In 1810, when John Taylor wrote his introduction to Risdon's Survey of Devon, he was critical of an earlier author called Chapple who had, in 1770, claimed that mining 'had hardly an existence' in the county. Taylor believed Chapple to be poorly informed 'for mining certainly was carried out in his time..' (Risdon 1811, xix).

William Pryce, writing in 1778, from his perspective on the west side of the River Tamar, was in no doubt as to Devon's insignificance in the mining stakes:

> *…more eminently ought that part of it called Cornwall to be distinguished, as having, perhaps, yielded more Tin in one year, than Devonshire has done in half a century*
>
> (Pryce 1778, i)

By the end of the 18th century activity was certainly intensifying but conflicting messages about the states of both tin and copper mining on Dartmoor continue from the various accounts. Again John Taylor writing in 1810 claimed that:

> *Some small quantities of tin which were produced from a mine on Dartmoor, by some poor men, about 30 years since [1780s], attracted the notice of some speculators, who engaged in numerous undertakings of the kind; and not finding partners who had confidence in them in the neighbourhood, endeavoured to obtain support in London, and with some success. Many mines were thus set to work, but, for want of skill or discretion, they proved generally unprofitable*
>
> (Risdon 1811, xix)

This rather scornful reference to the use of outside capital at tinworks as early as the 1780s, also indicates that although tin mines were established, they had failed. However, other tin mines are known from primary sources to have been working in the 1780s and 90s. Whiteworks for example had probably commenced at around 1786, though it was reported to be the only tin mine at work in the Forest of Dartmoor in 1790 (Greeves 1980). Curr Beam was well established in 1787, when shares were for sale (*World* 7.08.1788) and the Vitifer mines, parts of which had been established in the 1750s (above), were still working in the 1790s and were visited by Charles Hatchett in 1796. He reported a well-developed mine of 13 shafts, including an engine shaft of 40 fathoms, pumped by a waterwheel (Raistrick 1967, 22). Although ten years earlier various disputes between owners are recorded (*EFP* 28.09.1876), it is known that tin was being produced at this mine (*EFP* 01.11.1787). Hatchett also visited Wheal Jewel on the western side of the moor (the tin mine formerly known as Buddleybeer in Kalmeter's day) and Wheal Friendship, a copper mine which had quite recently commenced (Raistrick 1967, 21). Rev John Swete also visited Vitifer, which he referred to as the Warren, in 1797 and reported 'the bustle attendant upon work' and a 24fthm shaft being unwatered by a 36ft waterwheel. This mine, together with Bachelor's Hall and 'Fox Tor Meers' (i.e.Whiteworks) were, according to Swete, 'the whole of what were now worked on Dartmoor' (Gray 2000, 39). But others are known to have been active including Crane Lake which had 'recently started' in 1792 (Cook et al 1974, 164).

In 1799, what is stated to be a list compiled by the Comptroller of the Stannaries of all tin mines working on Dartmoor at that time totalled eleven, although several were said to be idle and only five were claimed to be either prosperous or 'raising tin' (Greeves 1997a, 7). The list includes some by now familiar names such as 'Videford' (Vitifer), 'Batchelors Hall', 'White Work' and 'Cur Beams' plus several lesser known enterprises.

A revival in tin mining was certainly in progress by the 1790s, inasmuch as some mines were in work, but this activity is likely only to have been a minor reaction to the price of tin which had risen conspicuously in the 1780s and 90s, from £59 per tonne in 1778 to £99 per tonne by 1800 (Schmitz 1979), a 67% increase. Tin was certainly being produced in the closing years of the century because the smelting house at Bachelor's Hall is known to have been in continuous production between 1798 and 1804, its most productive year being 1798 when 25,260 lbs were produced (Greeves 1996, 86).

Although the copper mines around Dartmoor were few, in the same period the price of copper, after two decades of approximate equilibrium at around the £80 mark, rose steadily in the 1790s reaching £148 per tonne in 1800. (Schmitz 1979, 269). According to Barton, the price of copper in the later part of the 18th century had been affected by the discovery of the metal close to the surface at Parys Mountain in Anglesey, from where it could be produced more cheaply. This had initially caused a depression for Cornish copper mines but by 1790 the Anglesey supply was failing, allowing this rise in price (Barton 1978, 39). Documentation hinting at the existence of major copper mines on Dartmoor since the time of Kalmeter is difficult to confirm, beyond those three marked on Donn's map of 1765, but by 1790 Wheal Friendship at Mary Tavy was in work (Hamilton Jenkin 1981, 33).

In 1822 Lysons wrote:

> *It appears that some copper-mines were worked in this county [Devon] early in the last century; but it was not before the commencement of the present that they were worked to any extent*
> (Lysons 1822, cclxxiv)

This would help account for the dearth of mid-18th-century references to copper mines in Devon and accords with the other known sources such as Kalmeter for the early part of the century. A major government enquiry, published in 1799 into 'The State of Copper Mines and Copper Trades of this Kingdom', failed completely to mention Devonshire or any of its copper mines (House of Commons 38, Geo iii), although it is known that Wheal Friendship and others were in work during that period.

Despite these signs of renewal, it is difficult to find any enthusiasm for mining from people not directly involved in promoting the industry in this period. William Marshall, the great agricultural improver, provides a particularly dismissive paragraph when writing of Dartmoor, although it does need to be

TABLE 4.3
Devon Mines listed by Lysons in 1822

Mine No.	Site No.	Mine Name	Parish	Date Last Worked
Devon Tin Mines Abandoned before 1815				
*62	66	Whiddon Down	Ashburton	1810
*328		Peckpits	North Bovey	?
*82	8	Bachelor's Hall	Lydford (FoD)	1810
*4	15	Brempts	Widdecombe	1807
*54	7	Huntingdon	Lydford (Fod)	1810
*317	50	Nuns	Walkhampton	1810
329		Gods Hall	?	1780
*41	42	Keaglesburrow	Walkhampton	1810
*330		Whitemoor Mead	Walkhampton	1790
*331	58	Ringmore Down	Sheepstor	1809
332		Crown Hill*		1809
*85	85	Wheal Jewell	Mary Tavy	1797
*333		Wheal Unity	Mary Tavy	1795
*334		Wheal Saturday	Mary Tavy	1809
335		Devil's Kitchen	Tavistock	1795
*36	82	Wheal Surprise	Whitchurch	1795
*336		Concord	Whitchurch	1795
*337		East Concord	Whitchurch	1795
*338		Wheal Mary	Walkhampton	1795
*104	97	Wheal Sidney	Shaugh	1795
*95	32	Furzehill	Buck Mon	1798
*340		Grimstone	Sampford Spiney	1805
Devon Tin Mines Abandoned after 1815				
*341		East Poldice	Buck Mon	
*342		Grenofen	Whitchurch	
*91	75	Wheal Lucky	Sampford Spiney	
Devon Tin Mines in Work in 1822				
*32	12	Vitifer	North Bovey	
*253	1	Ailesborough	Sheepstor	
*482	2	Whiteworks	Lydford	
*79	33	Gobbets	Widecombe (Lydford)	
*343	98	Wheal Union	Ashburton	
21		Bottlehill	Plympton	
Devon Copper Mines Abandoned in or about 1815				
*14	6	Ausewell Wood	Ashburton	1810
-		Molland Mine	Molland	1770
489		Wheal Oke	Okehampton	1808
- 356		? Wheal Bedford	Bridestow Tavistock	1809 1812
357		Wheal Peter	Tavistock	1811
358		Wheal Adam	Tavistock	1806
359		Great Duke	Tavistock	1813
360		Wheal Tool	Tavistock	1812
-		Holming Beam	Tavistock	1810
361		Marquis	Tavistock	1812
362		Wheal Tavistock	Tavistock	1810
*36	82	Wheal Suprize	Whitchurch	1812
*169	81	Virtuous Lady	Buck Mon	1807
*364		Crakern Beam	Buck Mon	1807
*366		Wheal Carpenter	Whitchurch	1803
367		Wheal Capeltor	Lamerton	1810
*53	98	Owlacombe	Ashburton	1815

Devon Copper Mines operating but not productive in 1815, mostly given up by 1822				
-		The Old Mine	North Molton	
344		Wheal Hope	Mary Tavy	
307		Little Duke	Tavistock	
349		North Wheal Crebor	Tavistock	
350		Wheal Georgina	Tavistock	
369		Wheal Henry	Bickleigh	
517		Wheal Burn	Tavistock	
351		William & Mary	Tavistock	
352		George & Charlotte	Tavistock	
353		Wheal Impham	Tavistock	
348		South Wheal Tamar	Tavistock	
Principal Copper Mines Worked in 1810				
*184	105	Wheal Friendship		
142		Wheal Crebor	Tavistock	
239		Wheal Crowndale	Tavistock	
148		East Crowndale	Tavistock	
141		Ding Dong		
344		Wheal Hope		
*345	69	Wheal Huckworthy	Walkhampton	
Principal Copper Mines working in 1822				
*184	105	Wheal Friendship	Mary Tavy	
239		Wheal Crowndale	Tavistock	
142		Wheal Crebor	Tavistock	
-		E & W Liscombe		
348		Wheal Tamar		
-		Unnamed	Buckfastleigh	

Table 4.3 Devon Mines and their working status listed by Lysons in 1822. (indicates mines within the study area)*

seen in the context of someone at the forefront of the agricultural improver movement who believed passionately that mining was a wasteful way to use land:

> *Formerly, this District was the principal seat of* MINING*; but, of later years, little has been done; until very lately; when the advanced price of tin induced the adventurous to re-open some of the old mines; and to try their luck in new ones: to the annoyance of the country; and with little profit to themselves*
>
> (Marshall 1796, 39)

4.2.2 The 19th and early 20th centuries

Mining in Devon in the first two decades of the 19th century was summarized comprehensively in Lyson's *Magna Britannia: Devon* (1822) from information provided by John Taylor, (Table 4.3). On Dartmoor, tin mines at Vitifer and Whiteworks were still operational and considered large scale as was Eylesbarrow, and several smaller mines all referred to as recently working. This source also reveals that 22 tin mines had been abandoned between 1790 and 1815 (Lysons 1822). Although Taylor can be considered a reliable source, it is known that other tin mines not on this list were in existence for parts of this period; Wheal Chance, Wheal Prosper, Morefield [Merrivale] Bridge and others were all being promoted in a prospectus of 1808 (DRO 1311M/Deeds/4/6) but not mentioned by Lysons; all have field evidence surviving. The high number of failures highlighted on the list could be accounted for by the steadily rising price of tin and copper (Table 3.3) which may have encouraged 'adventure' at locations unlikely to have been profitable. This would give credence to Taylor's words in 1810, quoted above. The rapidly rising price of tin in this period, which applies also to copper, was almost certainly a result of the disruption caused by wars with France, Spain and Holland, which spanned the period from the 1790s to 1815. In the case of tin, prices began rising immediately at the outbreak of war in 1792/3 and by 1814 had reached an all time high of £154 per tonne, which it would not achieve again until 1906 when it reached £178 (Schmitz 1979, 296). By 1817, following the end of the war, the price of tin had fallen back to its pre-1800 level of £92 and continued to fall in the following years, not to recover until the 1830s and 40s. The price of copper also continued to rise in the 1790s reaching its all time high of just under £190 per tonne in 1805, a figure it would never reach again from UK sources, and although following a downward trend thereafter, its decline was not as rapid as that of tin (Schmitz 1979, 269).

Lysons referred to the rise in the price of copper which he said 'gave great stimulus to the exertions of the miners', but, according to that author, only Wheal Friendship, Devon's largest copper mine at that time, and Wheal Huckworthy were producing copper on Dartmoor in 1811. Although by the time of his publication in 1822 other copper mines were operating to the west of Tavistock, Wheal Friendship and an unnamed mine at Buckfastleigh were the only working copper mines around Dartmoor, while several mines are listed as abandoned (Table 4.3).

In Taylor's introduction to Risdon in 1811 the tone is of mining in a period of recovery following a decline, but tin was still of little consequence

> *the search for tin… has been in a great measure discontinued, though it is not improbable that the present high price of that metal may now in some degree revive it.. and ..the mines of that metal are not important in value.*
>
> (Risdon 1811, xx)

Apart from Lyson's detailed discussion, general commentaries on Devon's, and more particularly, Dartmoor's mining industry are less common in the first half of the 19th century, probably because of a period of reduced activity. In 1802-3, yet another Swedish industrial observer toured Great Britain; Eric Svedenstierna, travelled across Dartmoor from east to west observing tin mines near the road (certainly the Vitifer mines) which he claimed 'are now little worked but bear witness to an earlier more intensive operation' and that at some 'unimportant mines' near Two Bridges, which possessed a smelting works (?Bachelor's Hall), there were high hopes of a renewed adventure (Dellow 1973, 29). Six years later, in 1808, Charles Vancouver mentioned two copper mines near Tavistock, some tin streamworks near Plympton and a copper mine at Buckland in the Moor, though the precise locations are not given (Vancouver 1808, 67-9). Anna Eliza Bray, who retold Dartmoor anecdotes and miscellany in her book *Borders of Tamar and Tavy*, in 1832 observed that:

> *The stream-works, though less productive than the mines, are still, in many instances, a source of profit to the adventurer.*
>
> *Dartmoor, it is well known, abounds with lodes of iron and tin; several of the latter have at all periods been very productive, and many more are now likely to be worked by the Plymouth and Dartmoor Company with spirit and success.*
>
> (Letter from R Southey, 2nd Oct 1835 in Bray 1879, 375)

Unfortunately it is not possible to be sure how well informed either of these sources were, although Bray was certainly very familiar with the contemporary Dartmoor landscape, judging by the majority of her writing.

Curiously, Henry de la Beche's otherwise highly detailed work *Report on the Geology of Cornwall, Devon and Somerset,* published in 1839, appears to have benefited from little new research on the state of Devon's mining industry and he repeats almost verbatim Taylor's statistics as published by Lysons 17 years earlier (De La Beche 1839), though he did add that Wheal Friendship and Wheal Franco were 'the most considerable copper mines in Devon' and were still at work, as was Bottle Hill, a tin mine, in Plympton (De La Beche 1839, 608). This is a general problem with the 19th-century sources which, although more detailed in their descriptions than those of previous centuries, are in some cases less useful in reality because many authors repeated, or in some cases plagiarized, the work of their predecessors, often with little acknowledgement, so the same 'facts' became blurred as they were presented with slightly different wording over a number of years and their accuracy was seldom questioned. Lysons list of 1822, using Taylor's information, was probably the last reliable source on the state of mining in the first quarter of the century, and was recycled by Rev Thomas Moore in *The History of Devonshire,* of 1829. William Crossing, the renowned Dartmoor writer active in the early 1900s, used Moore's 1829 list of mines (which had already been copied from Lysons/Taylor) as a benchmark as to how mining had declined since 1829 (Le Messurier 1966, 64) and indeed some of John Taylor's words in his introduction to Risdon of 1810, are to be detected in another of Crossing's works almost 100 years after they were written (Le Messurier 1967, 49). For Crossing, writing retrospectively, this is understandable but the idea that a writer as scholarly as De La Beche needed to use sources which were almost 20 years out of date to provide an account of the contemporary mining scene suggests that the economic significance of Devon's mines was perceived by him as sufficiently low or unchanging to require no further research.

However, it is clear from primary sources, especially the *Mining Journal* whose first issue was published in 1836, that the number of mining companies setting up on Dartmoor was on the increase as the 19th century progressed, several of which do not appear within these secondary sources. By the mid-19th century all of the 'new' companies exploring for tin, and a proportion of those for copper, were set up to work the sites of 'old' mines, many of which can be proven, through fieldwork or documentation (Table 6.1; 6.2; Appendix), to have been worked pre-1800. Many of the tin mines in particular are likely to

TABLE 4.4 Examples of mines worked on multiple occasions in the 18th and 19th centuries

Each date represents the formation of a new Cost-Book or Limited Liability company, the issue of a new lease to work the mine, or a date that a specific named company is known to have been operating.

Primary reference name	Dates and names of companies or owners	References	Cu	Sn
Arundell United	1852 (Arundell United);1858 (Devon New Copper); 1866 (Druid Mining Co); 1869 (New Victoria); 1872 (Ashburton Tin & Copper); 1874 (East Dartmoor Tin & Copper)	Newman 2003 , 173-218	✓	
Atlas	1855 (South Devon Iron & General Mining Co Ltd); 1858 (Atlas Iron & Tin); 1862 (Atlas Mining & Smelting Co Ltd); 1864 (Atlas Mining Co); 1889 (Atlas Tin Mining Co); 1896 (Atlas Mining Syndicate); 1918 (Albion Tin Syndicate Ltd)	Brook Index, Ilsington		✓
Ausewell	1724 (Ausewell); 1763 (Hazel Copper Mine); 1791; 1810; 1833 (East Wheal Hazel); 1859 (Wheal Hazel Mining Co)	Brooke 2001, 46; Phillpotts 2003; Newman 2004;	✓	
Birch Tor and Vitifer	1750 (Vitifer); 1780s (Dartmoor Mining & Smelting Co);1845 (Birch Tor & Vitifer Mining Co);1852 (Birch Tor & Vitifer); 1858 (New Birch Tor and Vitifer Consols Tin Mining Co); 1830s; 1840s; 1879 (Vitifer); 1904 (Birch Tor & Vitifer)	Brook Index, North Bovey; Broughton 1968/9, 7; Broughton 1971; Hamilton Jenkin 1974, 101-7; Hemery 1983, 614; Greeves 1986 21-44;		✓
Bertha, Lady	1855 (Lady Bertha Mining Co); 1880 (Lady Bertha United Copper & Tin Mining Co);1887 (Bertha Consols, Limited); 1895 (Bertha Consols Mining Co Ltd)	Brooke Index, Buckland Monachorum; Hamilton Jenkin 1974, 50-5	✓	✓
Brimpts	1797 (Brimpts); 1849 (Brimpts Tin Mining Co); 1852 (Duke of Cornwall Consolidated); 1853 (Devon Tin)	Le Messurier 1967, 50; Hamilton Jenkin 1974,95-6; Bird & Hirst 1996; Lysons 1822, 273		✓
Brookwood	1808 (Buckfastleigh Manor); 1840s (Macclesfield); 1854 (Brookwood); 1878 (South Devon United)	Hamilton Jenkin 1981, 92-100; Hall 2000, 126-30; Newman 2005, 2-3	✓	
Emma, Wheal	1808 (Buckfasleigh Manor); 1845 (Old Wheal Emma); late 1840s (Macclesfield); 1854 (Wheal Emma); 1878 (South Devon United)	Hamilton Jenkin 1981, 92-100; Hall 2000, 126-30; Newman 2005, 2-3;	✓	
Eylesbarrow	1804 (Eylesbarrow); 1814 (Ailsborough); 1836 (Dartmoor Consolidated); 1845 (Dartmoor Consols); 1849 (Aylesborough); 1851 (Wheal Ruth)	Cook et all 1974, 161-214; Hamilton Jenkin 1974, 87-90; Newman 1999, 105-48		✓
Fortune, Wheal	1806 (Merifield Bridge); 1840 (Wheal Fortune); 1852 (n/k); 1858 (Staple Tor); 1869 (Merrivale Bridge); 1872 (n/k)	Greeves 1976, 3-5, 11		✓
Frederick, Wheal	1845; 1850; 1859 (Wheal Frederick); 1853 (Duke of Wellington Consols); 1872 (North Dartmoor Tin Mining Co)	*MJ* 05.02.1853; Brooke Index. Lydford; Greeves 2003, 22-4		
Furzehill	Pre1724 (Forest Hill); 1797 (Furze Hill Tin Mine); 1860;	Hamilton Jenkin 1974, 83-5; Burt et al 1984, 61-2; Brook 2001, 11		✓
Gobbett	1812 (Gobbitt); 1836 (Wheal Gobbett – Dartmoor United Mines); 1840 (Dartmoor Consols); 1864 (Swinecombe Vale Mining Co Ltd);1869 (Gobbett Mine); 1871 (Gobbett Tin Mining Co Ltd); 1881 (Gobbett Tin Mine Ltd);	Hamilton Jenkin 1974, 98; Brook Index, Lydford/Holne; CRO DD/STA/VI/711/5; CRO DD/STA/I/246/1-10		✓
Hexworthy	1849 (Wheak Unity);1852 (Holme Moor and Henroost United); 1889 (Hexworthy); 1905 (Dartmoor Minerals Ltd)	Greeves 1986, 4 - 20		✓
Huntingdon	1758 (n/k); 1815 (n/k); 1837 (East Wheal Rose); 1850 (Dartmoor Forest Mine); 1851 (Avon Consols); 1857 (Huntingdon Mining Co); 1859 (Huntingdon Tin); 1863 (Devon Wheal Vor); 1864 (Devon Consols Tin); 1866 (New Huntingdon)	Brook 1980, 75-6; Hamilton Jenkin 1981, 85-6; Greeves 2001, 8-10; Burnard 1891, 111; Brooke Index, Buckfastleigh		✓
Mary Emma, Wheal	1849; 1852; 1857	Collins 1912, 530; Dines, 1956, 711; Hamilton Jenkin 1981, 27; Burt et al 1984, 82; Rowe 1896, 270		✓
Whiddon	1689 (Whitton Downe); 1724 (Whiddon Down); 1757 (Whiddon Tin Mine); 1763 (Widdon Smelting House Tin and Copper); 1807 (Whiddon Down Mine); 1840-50 (various); 1857 (Wheal Widdon); 1871 (Whiddon Tin Mine); 1885 (Whiddon Mining Co) Down	DRO DD 35531a; Brooke 2001, 46-7; CRO R/4998; DRO 1311/M/Deeds/4/6; Donn 1765; Dines 1956, 736;	✓	✓
White Works	1799 (Simpson & Co); 1808 (Webb); 1819 (Denis); 1847 (Wheal Industry); 1863 (Whiteworks alias Wheal Industry); 1868 (Whiteworks Mining Co); 1876 (New Whiteworks Mining Co); 1884 (Bawden)	Greeves 1986, 2; Greeves 2002, 3-6		✓
Virtuous Lady	1724; pre1809; 1844; 1855 (VL and South Bedford); 1859 (VL Mining Co Ltd)	Brooke 2001, 13; Brooke Index, Buckland Monachorum	✓	

have pre-1700 origins or earlier, although the creation of new mine companies to work these sites was to continue into the 20th century. For several of the mine companies documented, no location or field remains can be identified and it has to be assumed that work on the ground never commenced. Table 4.4 shows 19 case studies based on primary documentation, all either large or small-scale productive mines or developed prospects, each of which demonstrated what is here termed 'intermittent continuity' typical of the mines in this period; they were active in sporadic bursts dictated by whether a company was working the mine and was solvent and responding to the economic factors of the day.

Investment in Dartmoor mining was particularly active in the 1850s - 70s with many new companies being formed to rework established, though often disused, mines. A simple economic explanation for this burst of activity could be that the price of both tin and copper was again trending upwards (Table 3.3). Tin, having reached a low of £61 per tonne in 1843, rose rapidly to a peak of £134 in 1860, then declined briefly in the early 1860s to peak again at £150 in 1872 (Schmitz 1979, 295-6). Copper meanwhile, after remaining within the £80 - £90 bracket in the 1840s and early 1850s, rose to a moderate £124 per tonne in 1854-5 and stayed fairly high before a gradual decline, which saw prices go lower than the pre-1800 rates at around £60 by the 1880s, and eventually slumping to a catastrophic £43 per tonne in 1886 (Schmitz 1979, 270-1).

Several new companies were formed to work virgin deposits of copper around Ashburton in the 1850s, when the price was strong, including Arundell (1852), and Queen of the Dart (1854), together with a number of prospects including Borro Wood (1856), King of the Dart (1857-8) and Devon Great Elizabeth (1857); these were new mines though they failed to become developed. In the year ending September 1856, 23 Devon mines had recorded outputs of copper, including 10 on Dartmoor, though only five tin mines were productive (Hunt 1857, 20). In 1858 Richard Tredinnick, a mine engineer and share dealer, summarized the investment potential for copper mining activity for that decade in Devon and Cornwall; apart from glowing reports on Devon Great Consols and Wheal Friendship, he was generally dismissive of Devon's copper mines where he claimed:

> *..large and rapid gains are mostly acquired from young and shallow progressive undertakings, yet I regret to add, that Devonshire is at this time peculiarly exempt from any which I can refer the reader with some degree of confidence as regards future permanent and profitable yield.*
> (Tredinnick 1858, 130)

He mentioned only three other mines within Dartmoor's borders, Sortridge, North Robert and Lady Bertha, though was sceptical of their investment potential, describing the latter:

> *..the frequency and smallness of deposits (if Mr Ennor's theory, viz., that minerals grow like vegetables, be correct) unfortunately in this instance resemble more the sprouts than the fully ripened and mature broccoli.*
> (Tredinnick 1858, 131)

A useful, and probably accurate, snapshot of the Dartmoor mining industry is available between 1859 and 1870, when J. William's *Cornwall and Devon Mining Directory* was published annually, which listed active and recently stopped mines. In the 1862 volume, seventy-two mines are listed for Devon of which as least 39 may be identified as lying within the study area of Dartmoor and its immediate environs. Remarkably, the number of employees at each mine was recorded totalling over 1000 people employed in mining on Dartmoor and its borders (Williams 1862, 99-116); for a rural area this was a significant workforce. By this time however, tin mining was the poorer relation where copper mines dominate the statistics.

Robert Hunt, the 'Keeper of Mining Records', wrote in 1865:

> *Although at the present time there are not more than a half-a-dozen places on Dartmoor where tin is worked, the evidence of there having been extensive mining operations in former days has been very strong*
>
> (Hunt 1865,42)

While some commentators were reverting to the past glory of the tin streamers theme, a more forthright comment was made in 1862 by H C Salmon, editor of *Mining and Smelting Magazine*:

> *During eighty years of working the Dartmoor district has only made one profitable mine – Wheal Friendship – against an expenditure of probably a million of money*
>
> (Barton 1967, 111)

Salmon is believed also to have been the (anonymous) Truro Correspondent of the *Mining Journal* (Hall 2000, 4), and was clearly a knowledgeable and well-informed figure.

Nevertheless, tin was being produced on Dartmoor, however profitably, and Hunt mentions Vitifer in particular as making a profit. During the 1870s, new companies were also founded to work tin deposits at sites which had been worked in the remote past but not to any notable extent in the 19th century, including New Vitifer Consols, launched 1867, Holne Chase and Great Wheal Eleanor both launched in 1874 and Great Week in 1886, while several defunct mines, which had seen previous 19th century activity, were revivified, such as North Dartmoor Consols and East Vitifer. All these mines, though benefiting from extravagant investment in surface machinery, were short lived and produced little ore (Burt et al 1984, 35; 48; 68; 74; 114). Other renewed tin mines such as Hexworthy, which was back in work in the 1880s, proved slightly more enduring (Newman 1996, 3). This activity may once again be seen as a response to the high price of tin, which, in the 1870s had been prompted by a break in the supply of the metal from Malaya; a period described by Barton in a Cornish context as 'The Great Tin Boom' (Barton 1967, 136).

From the mid 1850s onwards, activity at Dartmoor's productive mines can be gauged with more accuracy, due to detailed sources becoming available as a result of government involvement in the regulation of mines. Mineral statistics, published annually by the British Geological Society from 1853 and later by HM Inspector of Mines from 1882, reported on the output of individual mines. Following the Metalliferous Mines Regulation Bill of 1872 (35 & 36 Vict.), an annual report of the mines inspectors also recorded details of mines in work from 1872 to 1892. These sources together remove some of the uncertainty which surrounds the dates and levels of activity at individual mines, although it is possible that a small number of non-producing mines escaped the notice of the inspectors. For the 1850s these sources confirm that copper mines were the more productive; in 1853 for example nine Dartmoor copper mines produced 5,240 tons (5,292 tonnes) of ore, while only four tin mines recorded a total tonnage of 54 tons (54.5 tonnes) with a value of £3173.

Despite a growth in mine numbers in the 1850s-80s, few became really productive. The dramatic fall in the price of copper in the 1880s, caused the end of most copper mines in Devon and, with only a few tin mines continuing on Dartmoor, the entire mining industry was facing its final demise in the last two decades of the century. The figures from HM Inspector of Mines Reports show that in 1873, 26 mines were recorded working within the study area, including twelve tin and seven copper. By 1883 only nine mines were recorded as in work (five tin and four copper), but an additional seven are listed as inactive (Insp Rep for 1883). In 1893 only 1 copper mine, Lady Bertha, was producing ore and there were 5 tin mines (Min Stats 1893).

By the 1890s, contemporary commentators were writing the obituary for mining on Dartmoor, in terms Kalmeter would have found familiar 170 years earlier. Lloyd Warden Page for example, in his *Exploration of Dartmoor* in 1892:

> *The mining of Dartmoor is now almost a thing of the past……Here and there on the borders a few mines of tin or copper are working and in the heart of the moor Vitifer under Hamledown still makes some return; but with these exceptions, Ichabod may be written over the mining of Dartmoor.*
>
> (Page 1892, 25-6)

and J Brooking Rowe in 1896 claimed:

> *For some years past, the mining industry in Devon has been declining, and on Dartmoor and its precincts it is practically extinct*
>
> (Rowe 1896, 268-70)

Rowe noted the low tin output recorded in the mineral statistics of 1893 which by then had an annual value of only £2,779.

In 1900, in a series of retrospective articles entitled collectively *A Hundred Years on Dartmoor*, William Crossing described how the mining industry was by then almost totally, but not completely, abandoned and he listed the abandoned moorland mines by name, although stating that Hexworthy and Golden Dagger were both still working for tin on the high moors, and others were working in the borders (Le Messurier 1967, 50-1). The latter would certainly have included the copper mines of Wheal Friendship, which he mentioned by name, and Ramsley Mine at South Zeal, which did not close until 1909, when it was claimed to be the last mine in England to be worked exclusively for copper (Hamilton Jenkin 1981, 76). These plus the tin mines of Atlas, Owlacombe/Stormsdown, Vitifer and Devon United are the only remaining mines with recorded output for the years between 1900 and 1913 (Burt et al 1984). Of these, underground activity at Vitifer had probably ceased by 1913 and Golden Dagger continued producing tin by reprocessing waste dumps until the 1930s, although again, underground work had been discontinued by 1914 (Greeves 1986, 24; 45), while Devon United continued producing tin and arsenic until closure in 1922 (Richardson 1992, 53).

Thus, with only a mere handful of mines remaining in work at the outbreak of The Great War in 1914, the search for tin and copper on Dartmoor in any commercial sense, was virtually at an end.

4.3 DISCUSSION

The tinners of Devon enjoyed well-documented prosperity in the medieval and post-medieval period, when output from the streamworks of Dartmoor and its borders reached its zenith and shallow lode workings came into production. This prosperity was in decline by the 17th century and by the mid-18th the industry was stagnating never to recover to its former level of productivity. The mining industry of Dartmoor in the period 1700-1914, cannot in any terms be considered prosperous by comparison with earlier times, especially when stood statistically alongside that of Cornwall which produced tin and copper on a massive scale in the same period. For the whole of the study period contemporary observers, often those not associated with mining, rarely write of prosperity when referring to Dartmoor’s mines, most alluding to the past success of the tinners, juxtaposing this fact with the run-down state of the industry in their own time. But many writers with expert knowledge of mining also wrote scathingly of Dartmoor’s potential.

Regardless of the impression provided by literature, mining activity, though probably on a very small scale, continued intermittently through the 18th century and by the 1790s the district as a whole was regaining momentum, stimulated initially by the demand for home-produced materials during the wars with France. New mining companies were created and old mines were reopened, often on multiple occasions throughout the study period as companies failed, and new capital continued to be raised to invest in fresh ones. Fluctuations in ore prices may be seen as one of the major agencies of this expansion and contraction. Higher prices would prompt the creation of new adventures but conversely the marginal nature of Dartmoor's mineral resources, discussed in Chapter 3, and the smaller scale of the enterprises that resulted, generally made them equally susceptible to depressed markets. But in contrast with the downbeat commentaries of the many writers cited above, optimistic accounts describing Dartmoor's mineral wealth and future prospects were provided by those involved in promoting and prosecuting mining in this district and who considered that the universally acknowledged past success of the district could be perceived as a positive indication of future wealth; this topic is expanded in Chapter 5.

Implicit in all the writings and primary documentation that mention mines and the companies and adventurers that worked them, is the role of capitalistic organization within the mining industry on Dartmoor, the foundations for which had been developing long before 1700. Although the arrival onto the scene of Elizabethan mining entrepreneurs such as Adrian Gilbert and associates signals a somewhat false and premature start to the mining of copper by companies of adventures, it serves to inform us that the need for people in possession of the resources and expertise to carry out hard rock mining was triggering activity as early as the 16th century. Although the medieval and post-medieval tinners enjoyed relative freedom to pursue an industry which was not fettered by the need for capital, their mode of organization would also become transformed as tin mines replaced tin streams. Much of the post-1700 activity discussed above was enabled by the capitalisation of mining on Dartmoor and it is to this topic that attention of this discussion must now turn.

CHAPTER FIVE
A SOCIAL CONTEXT

5.1 THE NATURE OF CAPITALISM IN WESTCOUNTRY MINING

It has been explored in Chapters 3 and 4 that numerous external agencies influenced the development of mining, even in a discrete district such as Dartmoor, and the behaviours of those responding to such agencies are manifest in the material evidence. Ultimately patterns of consumption, the demand for metals and a correlative fluctuation in the prices of ores, as discussed in Chapter 3, have to be seen as the main drivers behind change in an industry that by the 18th century, had become dependent on capital investment, and were the key to its prosperity or decline. However, local factors also offer important social context as to how a mining district was able to function within this wider world-system. Johnson has commented that ideological, economic and social differences exist between various localities; he has suggested that although groups separated by locality were participants in an essentially core capitalist system, the historical antecedents of such groups affected the trajectories of their development (Johnson 1996, 9). Such considerations may assist not only in explaining the uniqueness of Westcountry mine organisation but also the differences between the industries of tin and copper mining in this region, in terms of a capitalist model. Both industries, despite their differing origins, had by the 18th century, through technological innovation and the unique practical challenges set by the separate ores, contributed elements towards shaping the organisation of Westcountry mining at the dawn of the 18th century; tradition and custom particular to the locality must be seen as the strongest of these elements. As one mid-19th-century writer expressed it:

> *The present laws related to mining are founded less on the civilisation and legislative ingenuity of the times in which we live, than upon habits and immemorial customs which have descended to us from the earliest ages.*
>
> (Bartlett 1850, 21)

The historical aspects of mine organisation, investment practice and the legal framework under which mining was prosecuted are wide-ranging and the source material is potentially vast; however, the following discussion is necessarily limited to those aspects of the topic likely to have had most influence on change within the material landscape of mining on Dartmoor.

5.1.1 Organisation in the medieval period

The progression from a medieval industry to a fully capitalized mining business is particularly notable within the historical evidence of tin extraction in Devon and Cornwall. Medieval tinners exploited either the placer or 'stream' sources (Chapter 3 & 4), or shallow lodes, worked from the surface mostly, though not exclusively, through the investment of labour rather than capital. Finance was needed for equipment and wages (below) at the point of extraction and to cover the cost of ore dressing but stream tin, unlike ores mined underground from hard-rock sources, did not require costly extended periods of mine development before production could commence. As Finberg puts it:

> *It was a pursuit requiring no great fund of technical knowledge and no equipment beyond a pick and shovel, and perhaps a bucket….*
>
> (Finberg 1949, 170)

Copper and silver-lead ores do not occur as placers, consequently these industries were always dependent on the investment of capital for equipment and to sustain a workforce long enough to prospect and develop the mines, then continue the operation during exploitation. In the case of Devon's silver mines, producing a higher value product, the finance required was willingly provided by the Crown from the 1290s onwards (Claughton 1994, 54), hence the comparatively early beginnings of this industry. Copper, which was less valuable than silver but equally inaccessible in its hard-rock matrix, did not attract direct Crown investment but, from 1359, could be worked by royal licence through Letters Patent (Donald 1955, 96). However, the investment needed to develop copper mines economically was not universally available and is one significant factor advanced by historians (e.g. Barton 1961, 12; Buckley 2006, 84) for the retarded progress of the copper mining industry until the late 17th century. Other contributory factors have been advanced by Hammersley (1973) and Burt (1991), discussed in Chapter 4. It was the comparative ease with which stream tin could be exploited on a small scale that allowed a tin 'industry' to become established, together with its customary rights and traditions, so much earlier than for the other metals in south-west Britain, which were constrained by the difficulty of exploiting hard-rock sources.

The organisation of the tin industry in the stannaries of Devon and Cornwall, which had been established for at least 500 years by the end of the 17th century, has its origins in 'free mining'; a system of rights, laws and customs which were in place at several other mining districts in the UK including Derbyshire, Mendip, Forest of Dean and Alston Moor (Lewis 1908, 79). Although the precise details of how this system evolved in the stannaries are obscure, the basis of free mining was that mineral extraction would take place on land which was private property, but the tinners had the right to exploit any place they believed to be worthwhile, as long as they paid 'dues' to the landowner and taxation to the Crown, known as 'coinage duty', on the finished metal (Hatcher 1973, 48). Although the industry was regulated by the Crown for taxation purposes, the mines were not 'Royal mines' owned by the Crown (Lewis 1908, 78) as in the case, for example, of Devon's medieval silver mines, and tin mines were not affected by the need for Letters Patent, as were all copper mines until 1689 (Donald 1955, 96). The tinners' rights, manifest in the practice of 'tin bounding'(see Chapter 4) and a number of additional customary privileges that were overseen by the stannary courts, were in place at least by the late 12th century (Lewis 1908, 35).

Among the first historians to subject the workings of the stannaries of both Devon and Cornwall to analysis was Lewis (1908), who noted that mining organisation within the stannaries had its origin in groups of free-mining adventurers, i.e. working shareholders, but progressed to one of investment of capital by outsiders with waged labourers and skilled miners performing the work (Lewis 1908, 202). Lewis believed that this transformation had occurred over an extended period from the middle ages to the 18th century and he observed:

> *That mining… was one of the first industries to generate capitalistic organisation, there can be little question………in advance of the growth of capitalistic enterprise in other branches of industry*
>
> (Lewis 1908, 197)

Indeed Hatcher noted that ‘all writers on the history of the stannaries’ have discerned the early presence of capitalism and he cites several other versions (Hatcher 1973, 50). The concept is both supported and illustrated by the famous case of ‘Abraham the Tinner’ in 1357, quoted by most previous authors on this subject (Lewis 1908, 189; Hatcher 1973, 62; Gerrard 2000, 40; Buckley 2006, 45-6), who was the owner of four Cornish streamworks and two mine works, employing over 300 men, women and children, indicating at least that waged labour was established in mining by the 14th century. According to Hatcher, this operation was exceptionally large (Hatcher 1973, 62) and if so, it is likely that smaller enterprises existed alongside the larger ones, especially in Devon where the trade was on a much smaller scale (*Ibid,* 74).

Further clues as to the organisation of labour and ownership of tinworks are found in a Cornish account of over 200 years later in 1586, when Thomas Beare, The Bailiff of Blackmoor Stannary, recorded a hierarchy of tinners (Buckley 1994, 7). R H Worth broadened this study to include other 16th-century sources, and established that there was up to five tiers in this system:

Spalliards – men working by the day for a fixed wage

Labourers

- – men working on yearly contracts for a fixed wage
- – *dole workers* given a part-share in their master’s profits for half the year but worked the other half for a wage

Tinners – the man who owns a share in the work and performs the labour himself

Master Tinners – owners of shares in the work who either employ labourers or set their rights (in the case of dole workers), taking no part in the labour themselves (Worth 1910).

An additional category fell somewhere between tinners and labourers who took half tin, half wage. These were similar to dole workers but were actual partners in the work for the year they were contracted.

Although little detail is available from before the 16th century, from at least that time, many tinners were stakeholders in their own industry rather than simply waged labourers, and the freedoms of this system meant that personal gain of individuals could be achieved through either a greater investment of their own labour or through delegating labour by paying others. Given that many parallel stannary traditions, such as tin bounding (Chapter 4), had been developed as early as the 14th century, there is good reason to believe that these organisational elements had much earlier origins than the sources currently allow with certainty. Indeed, the practice of tin bounding and the organisational scheme of dividing the tinworks into shares or 'doles' were complementary; the latter ideally suited to the former as a way of distributing the burden of investment and labour once the bounds had been secured.

Lewis's statement (above) therefore is certainly correct, and many of the components required for the genesis of a capitalist system of working were in a germinal form in Westcountry tin works by the 16th century or perhaps earlier, including the concepts of shareholders, partners, dole-workers and waged labourers, which would form the basis of mining organisation in the 18th and 19th centuries. Although much of Lewis' and Worth's information was from Cornish sources, Greeves has demonstrated that Devon's tinworks were organised similarly and that those involved at shareholder level, were mostly people of local origin (Greeves 1981, 72). Also, that the classes of tinner found in Cornish sources cited by Worth, occurred in a Devon context too (*Ibid,* 75). Many of the tinners who coined tin in the 13th century were also artisans and husbandmen, working for tin perhaps being an additional form of income (Finberg 1949, 170), and by the 16th century 'all ranks of society' were presenting tin for coinage (*Ibid,* 172). These data have been further reinforced by an area-specific study of the Meavy Valley on south-west Dartmoor, which confirmed that a proportion of the farm tenants in the parish of Walkhampton also held shares in tinworks in the same or near locality between the 14th and 17th centuries (Newman 1994, 229-32). However, as Hatcher observed through examination of the statistics of the coinage returns and the limited number of individuals who coined tin (Finberg 1949, 155-84), that the Devon tin industry should be considered as having been conducted on a very much smaller scale than that of Cornwall, with smaller units of production and 'less highly capitalized' (Hatcher 1973, 47). Devon, he claims, was 'the province of the small-scale operator' (*Ibid,* 76).

5.1.2 Joint adventure in the early modern and modern period

There are two essential differences between the tin and copper industries in the south-west in the 18th and 19th centuries. The first was that tin smelting always took place within the county where it was extracted, either Devon or Cornwall, and had done since earliest times (Barton 1967, 18-20). This was because, prior to 1838 when the practice was abolished (Pennington 1973, 145), finished tin could not be sold outside of either county before taxation or 'coinage' was paid on it. No such restriction applied to copper ore which was normally shipped to South Wales for smelting, especially during the early years of the 18th century. This contrast also highlights the other main difference between the two which was that tin was an ancient industry, as outlined above, with long-established customs, privileges and regulations (Barton 1967, 18-20), whereas copper mining, once freed from the constraints of the Society of Mines Royal in the late 17th century, could be prosecuted in a more businesslike fashion and was, even during that episode, a fully capitalized industry. For the tin industry there is a connection between the former point and the latter, inasmuch as the coinage was paid on finished, i.e. smelted, tin and was therefore inextricably linked to the smelting process. Because coinage took place at sometimes infrequent intervals during the year, tinners, particularly the small-scale producers, had to rely on advances from the smelters and 'middlemen' to finance their industry (Hatcher 1973, 50). This marked the beginning of the need for a flow of capital into individual mine enterprises which, during the later 17th century, would develop into a system of investment. Hatcher considered that the cycle of debt that this system created, enabled:

> *the emergence, at an early date, of entrepreneurs and middlemen who earned their living by servicing the needs of the producers, and the eventual… subjugation of the latter by the former*
> (Hatcher 1973, 43),

as more individuals from outside of the core mining community began to invest in mines.

During the 17th century the tin industry was moving towards more exploitation of lode ores through underground mining, necessitated by the gradual depletion of stream sources (Chapter 4). Shallow tin mining (i.e. underground), as described in Chapter 7, had been standard practice since at least the 16th century in Devon, but successful mining at the increasingly greater depths needed to win the ore, required a different organisational arrangement to that of streamworking and surface lode works, as considerable capital was necessary to develop the mine over an extended period. Indeed the working methods became akin to those which had long been required to exploit silver and copper. Traditional partnerships made up of a blend of 'such Tinners as worke to their owne behoofe, or such adventurers as put in hired labour' (Carew 1602, 10) were still the normal practice in the early 17th century but a greater element of financial risk was present. Richard Carew frames this concept very well in his account of 1602:

> *When the new found worke intiseth with probabilitie of profit, the discoverer doth commonly associate himselfe with some more partners, because the charge amounteth mostly verie high for any one mans purse… and if the worke doe faile, many shoulders will more easily support the burthen*
> (Carew 1602, 10)

What Carew is describing in the early 17th century was, however, still very much an industry organized and controlled at a local level. Later that century the 'gentry' began to assume greater control (Buckley 2006, 75) and there was a move from a medieval tin industry, governed on the basis of customary practice and privilege, to one which operated on the basis of capitalism, financed by joint adventures, working mines owned by the gentry and worked by waged miners.

It has been suggested that changes in the political and financial climate, following the so-called 'Glorious Revolution' of 1688-89, provided a more nurturing environment, conducive to joint adventures in mining (Buckley 2006, 77). This was particularly so for the mining of copper, which regardless of any changes that had resulted from the abolition of the Mines Royal in 1689, was enjoying an increase in demand. This coincided with new discoveries of the metal and a changing commercial climate which created surplus capital to be invested in mines (*Ibid,* 84). Unlike tin, copper setts could not be 'bounded' on the lands of others without permission in either county, which allowed land owners themselves to invest in and benefit more fully from copper deposits discovered on their estates.

The arrival of John Coster of Bristol onto the Cornish scene, represents a potentially important watershed moment in the progress of copper mining. Coster ran a copper smelting operation in South Wales in the 1680s; to ensure supplies of ore, he was also investing in Cornish and Devonian copper mines and, due to his success, other speculators from outside the region felt encouraged to do so as well (Barton 1961, 12; Buckley 2006, 85), marking a distinct contrast to the strictly local makeup of tin mining adventures. This culture-change can be seen within a national context whereby the mining districts in England and Wales had been 'almost entirely self-sufficient in capital, entrepreneurship, expertise and labour' (Burt 1977, 7) but that this was changing by the end of the 18th century.

The prosperity of Coster and his peers was dependent on copper mining becoming more reliant on innovative technology to achieve mines of the necessary depth, and these developments will be discussed in Chapters 7 and 8. For the technology to be developed, a different type of capitalist was needed. To take advantage of the new technologies required to follow ore bodies deeper, or work lower quality ores on a larger scale, required the traditional independent groups of working miners to make way for new, externally funded, professionally managed enterprises employing full-time wage labour (Burt 1995, 23)

5.2 MINE ORGANISATION

By 1700 copper and tin mining were both rapidly transforming into globally significant industries, responding to the economic, technical, social and political opportunities of the times. But in the Westcountry, the mining industry still owed much to the traditions of the medieval tinners, whose group identity was perpetuated into the modern mining era (i.e. post 1700). Indeed the organisation of mining companies, as manifest through both the cost-book and tribute systems (below), owe much to the customs that prevailed in the heyday of the Stannaries.

Among the key 19th-century texts on mining organisation is John Taylor's *On the Economy of Mines in Cornwall and Devon* (1814, 309-27), in which the author questions the efficiency of mining industries in countries where government-supported operations were in place, over those in Britain which 'rely for their success upon their own resources, and the spirit and energy of their owners'. Taylor describes the benefits of the management system which had evolved in Cornwall and was also in use in Devon, offering five general headings:

- The nature of agreement between the owners of the soil and the mine adventurers
- The arrangement between the partners or adventurers themselves and the system of control and management appointed by them
- The mode of employing and paying the miners and workmen
- The purchase of material
- The sale of the ores

All of these attributes may be seen as having antecedents within the early tin industry, but the organisation of the adventures and the mode of employment (2 and 3) are particularly germane to the development of mining capitalism.

5.2.1 Mining companies, the Cost-Book System and limited liability

The cost-book system is one of the unique manifestations of capitalist enterprise in the Westcountry mining industry, where joint adventures were undertaken by what Lewis (Lewis 1908, 205) described as a 'loose association' of investors, formed around a core of adventurers who would jointly prosecute a mining property, leased by one or more of the group.

The origins and development of the cost-book system or principle, have been outlined by historians of the 20th and 21st century including Lewis (1908, 205-7), Pennington (1973, 147-96) and Buckley (2006, 154). Very much earlier, Pryce had described the components of cost-book adventure in 1778 but did not use this term (Pryce 1778, 174) and other contemporary accounts of the cost-book principle were provided by Taylor (1814, 313-16) and Bartlett, whose 16-point guide stands out as a particularly concise discourse regarding complexities of the system (Bartlett 1850, 24-5). Pennington, who has provided a modern historical explanation, considered that the type of mining enterprise, which in 17th-century terms would have been referred to as a 'mine adventure', (e.g. Carew 1602 above), by the 18th century had become the cost-book company (Pennington 1973, 153). The various merits and disadvantages of the cost-book system have been much discussed by economic historians, including Burke and Richardson (1981, 4-18) Burt and Norikazu (1983, 30-41) most recently, but lie outside the scope of this thesis.

The essential basis of a cost-book company was that a lease on a mining sett would be obtained by a nucleus of adventurers, known as 'in-adventurers', in a similar manner as the earlier tinners had when operating streamworks. Shares were transferable and further capital could be raised by selling shares to outside investors or 'out-adventurers', although the total number of shares was fixed. All employer and material expenses, together with the list of shareholders were entered into a single book, maintained by a purser, hence the name 'cost book'. The cost-book was 'wound-up' at bi-monthly meetings when all debts, wages and dues were settled and any trading profit was paid as a dividend at so much per share. The disadvantage of this system was that no capital from profits could be held in reserve as might be needed at times of loss, e.g., during extended periods of underground development, and additional costs had to be raised through imposing 'calls' on each share. The purser was the only company official among the adventurers and took responsibility for all financial matters, including acting on behalf of the company when sued by creditors.

Both Lewis (1908, 205) and Buckley (2005, 154-5) state that principal in-adventurers in a cost-book company would include a number of local merchants with a vested interest in selling goods and services to the mine, such as timber, coal, candles, etc. Under these circumstances, keeping the mine operating was, for the in-adventurers at least, as important as profits accrued from producing metals. John Taylor observed that such adventurers, when owning a majority share, have 'a concurring interest in allowing exorbitant prices and unlimited consumption' of the products and materials they were supplying (Taylor 1814, 323). It has not yet been possible to prove that this was the case in the Dartmoor cost-book companies, although it seems very likely and detailed documentary research outside the brief of this thesis would clarify this issue.

The concept of the cost-book company is an important contextual consideration in the development of mining organisation in the Westcountry because it evolved from, and was enshrined within, the traditions and laws of joint adventure of the tinners and the stannaries, but later became fundamental to the way mining was financed in both counties and for both metals, for most of the period covered by this study. Joint stock limited liability companies became an alternative option for mining companies in the late 1850s, following the Limited Liabilities Act of 1855. Although this new system slowly found favour in Devon and Cornwall, the cost-book system also continued in use, particularly among the richer mines of Cornwall. It became less popular in the 1890s (Burt & Norikazu 1983, 39) but remained in use until the early 20th century. Okehampton Mining Company Limited, registered in May 1857, was the first limited company to work a mine in Devonshire (BI, Okehampton).

The appeal of joint-stock companies with limited liability lay in the fact that there were no calls on shares once purchased, as in a cost-book company, and the risk taken on by each investor was limited to the value of his or her shares. This was a selling point in the prospectus for Great Wheal Eleanor tin mine in 1875:

> *The Company is a Limited Liability one; so that beyond the original cost of shares, the investor incurs no further responsibility whatever, and thus avoids the un-limited liability to repeated calls.*
>
> (*EFP* 27.01.1875)

Before 1855 liability for joint-stock company shareholders had been unlimited, which in a business with a high risk of failure, made investment less attractive. Theoretically therefore, following the 1855 act, greater numbers of investors and larger sums of capital could be raised and capital could be held in reserve. Management was delegated through an elected committee of investors, whereas in cost-book companies, shareholders could only have an input if they attended meetings in person, placing distant shareholders at a disadvantage. As with any form of investment, there is an element of risk, which is compounded by unscrupulous practice on the part of some. Bartlett claimed that his 1850 treatise was written in part to:

> *…lay down such rules for the guidance of capitalists, who desire to speculate, as shall effectually secure them from risk of fraud and disappointment …*
>
> (Bartlett 1850, 7)

Because cost-book companies had evolved from the system of tin bounds, in which shareholders were the co-owners, and shares were freely transferable, they had always had value as an asset, and for many shareholders they would become simply the stuff of investment and speculation. Shares in cost-book companies were being exchanged openly on the London market in the early 19th century (Burt & Norikazu 1983, 32), though the practice had commenced earlier. For those whose business was the inception of new mines, the fact that mine shares possessed a cash value introduced a new dynamic into the mining business and must have been influential in the way mines were developed, managed and financed, which includes the potential for fraud discussed below.

5.2.2 Tribute and Tutwork

In the 18th to 20th centuries, underground work in Westcountry mines was undertaken by miners on the basis of either Tribute or Tutwork. The latter involved payment of an agreed sum, a 'bargain', for measurable tasks, such as sinking shafts and driving adits, both paid at so much per fathom (Taylor 1814, 21). Tribute applied specifically to the raising of ore, and the bargain was based on a proportion of the merchantable value of the ore.

A tut-bargain was described by Pryce in 1778, claiming advantage of the system to the mine owner:

> *Everyone knows that a labourer employed for daily hire, will not execute that quantum of labour for his master that he will upon his own risk and account.*
>
> (Pryce 1778, 180)

According to Taylor, who described the system in great detail (Taylor 1814, 309-27), the great advantage of this system over any similar contractual arrangements was that the contracts were periodically put up for 'public auction' thus:

competition among the workmen is constantly excited as to cause the price of labour always to bear, on the whole, a fair proportion to the demand, and that superior skill and industry have their due advantage.

(Taylor 1814, 317)

The significance of these systems is in their continuance of some working practices first developed in the medieval streamworks. Lewis associates tutwork with that of the Spalliards of the 16th century (Lewis 1908, 202), who also were paid a fixed rate and had no further interest in the financial outcome of the enterprise. Tribute may also be identified with earlier classes of workers; in particular in Devon and Cornwall they can be compared with the dole workers contracted in the 16th-century tin streamworks, mentioned by Beare in 1565 (Buckley 1994, 7), and paid a share of the profit.

The residuality of these early traditions evident in aspects of later mine organisation, such as the cost-book system and the use of tribute and tutwork, offer strong evidence of antecedent practices having had a major bearing on the later developments and 'trajectory' of capitalist involvement in Westcountry mining.

5.3 THE CAPITALIZATION OF MINING IN DEVON AFTER 1700

Most of the analysis relating to companies, finance and organisation of Westcountry mining has been based, principally, on versions of events from Cornish sources with which most mining historians have engaged. By the early 18th century, and the commencement of the study period, one important difference between the two counties was that Cornwall was enjoying a growth in copper production and a steady trade in tin; in Devon, by contrast, following the English Civil War (1642-1648), tin production was declining rapidly (Table 4.1) while copper was still struggling to become established, with only a handful of mines producing ore. In Devon, in the early 18th century, the mining business was perceived as, if not completely moribund, then extremely poor (see Chapter 4). Although sources vary regarding statistics, in 1700 between 8000 and 20,000 people were employed in the Cornish tin industry (Buckley 2006, 76), such was the economic importance of tin. No such figures have been calculated for Devon but in the same year, Cornwall produced 3,151,504 lbs (1,406 tons) of tin whereas Devon produced 47,384 lbs (21 tons) (Lewis 1908, 256), i.e. 1.5% of Cornwall's total. In 1700, at the commencement of the study period, any correlation regarding aspects of the progress and scale of mining in Devon, for both tin and copper, has to be seen in the light of this statistic (see also Chapter 3, Table 3.1; 3.2).

Nevertheless, the two counties had much in common, particularly the customs and traditions of the stannaries which must have influenced the trajectories of capitalist progress of both in a similar way, albeit that the Devon mines were worked on a smaller scale.

In 1724 Kalmeter observed that in 1707 Marquise Copper Mine's discovery and inception was due to a combination of circumstances, but largely through the efforts of working adventurers:

> *She was first discovered seventeen years ago … when some workmen got together, took a sett or lease ….. from the owner of the land ……. They found some copper ore, and the work or place was called Bedford. Immediately after this some enterprising adventurers formed a company and took a sett of the ground above Bedford. They drove a level…… made parallel to the first level. Thereupon both workings were united and were and still are called the Marquis.*
>
> (Brooke 2001, 12)

Of Virtuous Lady copper mine Kalmeter states:

> *The adventurers are mostly of the Bristol company, and some of the miners, who are six in number, also have a share in it.*
>
> (Brooke 2001, 12)

John Coster's name is mentioned in association with Hocklake Mine (*Ibid*, 12), which strengthens the suggestion that adventurers from Bristol were as involved in Devon copper in the early 18th century, as Buckley and Barton inform us they were in Cornwall. Kalmeter also records that Ausewell Mine was leased by the Welsh Copper Company (Brooke 2001, 47). Clearly, individuals and companies from outside the county now had an important role in Devon's copper mining adventures, but working miners, such as those working at Marquise, were in some cases still more than mere waged labours. Although most of these early references are to copper mines not tin mines, Whiddon Tin Mine, near Ashburton is mentioned by Kalmeter where he claimed: 'work is carried on by twelve adventurers, most of whom are shareholders…' (*Ibid*, 47). Pennington considered that this breed of tinner was almost extinct by 1700 and adventures would be almost all from the merchant class (Pennington 1973, 149), but this, together with several similar examples described by Kalmeter in Cornwall, demonstrate continuance for this class of adventurers working on a small scale into the early 18th century.

Although documentation recording the division of shares in Devon tinworks survives from as early as the 15th century, written agreements setting out the financial commitments of adventurers and the formation of companies come much later. There is paper evidence of cost-book companies from as early as 1684 in Cornwall (Buckley 2006, 74), but no such direct evidence survives from Devon, although it seems likely that the early 18th-century companies mentioned by Kalmeter were working within a similar legal framework.

Several joint ventures of the 1750s have surviving documentation and are cited in Chapter 4, but these mostly may be seen as conventional tin bounding agreements telling us little about the adventurers themselves or the nature of their intended operation. However, indentures of 1767 survive concerning Whiddon Tin Mine near Ashburton. As above, this had been in work in Kalmeter's time (1724) and was also recorded in 1485 (Amery 1925, 52), 1514 (Brewer 1920) and 1689 (DRO DD 35531a). It was one of the few mines depicted on Benjamin Donn's map of 1765 (Ravenhill 1965), but in 1767 it was described as a 'Tinn Mine' with 'Two Stamping Mills and a Burning House' (CRO R/4998). The names of the adventurers are recorded, seven in total, described as sole owners and proprietors of the mine divided into 32 shares in which each of the seven had various allocations. The occupations of each are also provided, i.e. Merchant, Ironmonger, Tobacconist, Haberdasher of Small Wares, Shopkeeper and Gentleman. All may be considered local but none describe themselves as tinners. One of the adventurers is stated as having taken on the role of Treasurer and the document describes a loan of £500 to finance the construction of a smelting house. Clearly a mining company is what is being described here, not a more traditional streamworking partnership, although the document stops short of using the term 'cost book'.

An early surviving company prospectus was compiled by William Warren for the Devon Tin Mining and Smelting Company in 1787. Warren claimed to be the owner of 'very considerable extent of mines, but requiring a capital beyond his ability… he has now established a company..' (Warren 1787). The address of the secretary, Mr Bartlett, is given as Lambeth, London and this reveals an early incidence of remote London management. The locations of all these mines are not known for certain but the company had certainly failed by 1797 according to John Swete who visited Warren's ruined smelting house at Postbridge (Gray 2000, 41). When, in 1810, John Taylor wrote scathingly about a certain type of adventurers operating on Dartmoor in the 1780s, whom he termed 'speculators', he was probably referring to this enterprise, which he claimed having failed to attract local investors had resorted to selling shares outside of the county (see Chapter 4). The tone of Taylor's remark implies that seeking investment from far outside the county was perhaps an unusual and somewhat desperate measure at that time.

More detail concerning mining companies is available for the early 19th century. In 1818 it was recorded that Whiteworks Mine was a Cost-Book operation (Greeves 1980, 1) which may be the earliest thus described in Devon, but by that time it is likely that all tin and copper mines in the county were of this type. The major boom in the creation of Devon cost-book companies came between the 1840s and 60s, when the *Mining Journal* reported on their inception, progress and demise, often in quick succession. The majority of this information has been collated and summarized by Brooke (Brooke Index, Devon Library Services) and much of Brooke's Dartmoor data has been incorporated into the database of this thesis (see Appendix). The data helps reveal that the number of companies created far exceeds the number of sites where mining remains survive and it is clear that many a cost-book company proceeded no further than the paper stage. The same is true of joint-stock limited liability companies, which proliferated from the late 1850s and quickly became the favoured company format for Dartmoor mines thereafter.

5.4 PERCEPTION AND PERSUASION

The viability and perceived potential of a mine in the 18th and 19th centuries was often derived from knowledge of earlier mining endeavour at the site of a proposed adventure. This may have been gained from documentary records, oral information from those with memories, including passed-down memories, or more usually through the recognition by the miners of field remains that indicated the presence of an abandoned mine. In the period under discussion, possession of this information often substituted for prospecting, which according to Pryce was certainly a declining activity at tin mines in the Westcountry by the mid 18th century (Pryce 1778, 126)(Chapter 6). The knowledge of past activity alone would often provide sufficient stimulus for the re-commencement of a mine adventure, at times of increasing ore values. Of the documented mines collated for this thesis (Appendix), only one tin mine on the granite mass, where substantive field remains survive, is recorded as a 'new' mine; Bachelor's Hall, was said to have been discovered by chance in the 1790s through the act of cutting the Devonport Leat, south of Princetown (Hamilton Jenkin 1974, 94). However, for the remainder of the sample, documented 18th and 19th century tin mines are always on the site of remains which can, with a high level of confidence, be assumed earlier, where the nature of the surface earthworks indicate the use of the earlier techniques described in Chapter 6 (Table 6.1). One writer in 1851 claimed that:

> *It is seldom however, that a new mine is opened from the surface.....the reworking of those that are from time to time abandoned being in general sufficient to engage all speculators…*
> (Anon 1851).

The case of copper mines differed at the start of the study period because there was no legacy of earlier mines. However, by 1815, Buckfastleigh Manor Mine was being revived at a site said to have been worked '80 years ago' (DRO 1258M-SS-C[DL]E8) and Ausewell Mine, which had been in work in the early 1700s, was re-launched on several occasions in the 17th and 18th century (Newman 2004a) and was, in 1859, referred to as 'the once renowned' (*MJ* 12.02.1859). But although copper mines known to have been working just after 1700 were all reworked later, many new sites were opened from the 1790s onwards, including Wheal Friendship, Ramsley, Belstone and many of the smaller and developed prospects around Buckfastleigh, Ashburton and Horrabridge (Table 6.2).

The wisdom and skill of earlier generations of miners, referred to by later miners as the 'Old Men', was often cited by those who believed in, or wished to promote, the future of mining on Dartmoor and this is a recurring theme in mine prospectuses and publicity material created to promote new mining companies from the 1780s onwards.

Of Gobbett tin mine, whose shafts were sunk into the base of a large abandoned openwork, 'An Old Contributor' to the *Mining Journal* remarked in 1871, that the mine was 'celebrated for its tin production for as long past as the time of the prophet Ezekiel' (*MJ* 06.05.1871). Ten years later, when the mine was re-launched by a different company, it was claimed:

> *History is likely soon to repeat itself in this grand old tin mine. A splendid lode, 10 ft. in width, which has only been operated upon to the depth of 20 ft. by ancient workers, will in a few days be cut at 90 ft. deep, and miners who know the property are willing to work it at a tribute of 6s.8d. in the £."*
>
> (*MJ* 06.10.1883)

Similarly, East Birch Tor Mine, of which the shafts were also located within abandoned openworks and streamworks, was stated by its promoters in 1861 to have been worked 'from time immemorial and by the Ancient Britons' (BI, North Bovey). A very similar claim was made for 'Old Vitifer' in 1845 where in addition: 'The old workings were over a mile long and in one place above adit were opened by earlier workers as a stockworks' (BI, North Bovey).

In February 1870 it was reported that:

> *The celebrated old Wheedon [sic Whiddon] Tin Mine is about to resume working. Such fabulous stories of this sett are left behind, and even partially borne out by the remains of old stamps and piles of elvans, showing that at one time it must have returned large quantities of tin; but, low prices, inefficient machinery, and heavy Lords' dues, caused its stoppage…*
>
> (*MJ* 06.02.1870)

Clearly, ancient associations and recently abandoned activity were seen as a virtue for contemporary adventurers attempting to attract investors to a mining sett. Far from being viewed as likely to be exhausted, claims as to the early origins of a mine were seen as a benefit, indicating not just past wealth but future success. The adventurers often had no way of knowing the real date of operations at a disused mine other than those which had operated within the sphere of living memory, or with surviving documentary record of operations. In the days before a reliable geological science was available, one reason that these enterprises were viewed so optimistically was because of a belief that up to date technology and contemporary mining 'wisdom' would give access to parts of the lode which had been inaccessible to the earlier miners, who had been unable to pursue the lodes to their full depth. This theme is hinted at in the Whiddon reference above and was a common assertion made by adventurers, be it through sanguine optimism at the genuine enterprises, or as a means of encouraging speculation by less honest operators. In 1787, William Warren said of the 'old men's' efforts:

> *where rich ore was not accessible by the simple process then used, the miners had not perseverance or property to pursue or adventure in deeper researches*
>
> (Warren 1787, 1)

Almost one hundred years later the adventurers at Great Wheal Eleanor were using the same terminology to promote their mine at North Bovey:

> *Some of our best mines in Cornwall were discovered by sinking shafts on the old surface workings and coming upon the magnificent veins of which the men of ancient commerce only possessed means of what is called in mining phraseology "scratching the backs,"*
>
> (*EFP* 10.2.1875)

And this was precisely the process they were attempting at Great Wheal Eleanor.

In 1836 it was claimed of the Roborough mines:

> *The long celebrated lodes of Wheal Champion, and Wheal Fanny ……, after a lapse of many years, having ceased working in consequence of the then imperfect state of mining science, are to be recommended with all the advantages of modern experiences and machinery.*
>
> (*EFP* 11.02.1836)

In 1860, it was claimed of Furze Hill Wood Consols, a site which had been worked intermittently since at least the early 16th century (Greeves 1981, 319), that the shallow workings of the ancients had been successful 'with the chances of increased profits from the great advantages of cheap and effective modern machinery' (*TG* 10.08.1860) and that:

> *and if this mine proves as successful in depth to the modern miners as it was shallow to the ancients.. and another proof of their correct judgment as precedents for modern mines in this district…….*
>
> (*TG* 18.05.1860)

Five years earlier even more amazing claims had been made:

> *from the present appearance of the ancient workings of [this] mine, it must have returned the largest amount of tin of any mine in Devon and could be again at greater depth.*
>
> (*MJ* 21.04.1855)

Finally, in the 1851 prospectus for West Beam Mine, at the site of the largest and deepest former tin openwork in Devon:

> *..was extensively worked by Tin Streamers; but their operations were merely superficial, and the more perfect machinery of modern times has never been adequately tried in this district.*
>
> (DRO 1164b/ 11/8)

The assertion that earlier generations were capable prospectors but lacked suitable capacity for deep mining and had therefore passed over the ore at greater depth was a persistent theme. Much of this later sophistry is what would be known in share dealing circles as 'puff' but the idea that the 'old men's' workings or abandoned mines generally still had potential for profit may have been deeper rooted is borne out by some evidence from the late 18th century. Pryce for example noted that earlier miners did not have the benefit of adits to the extent that his generation possessed which had greatly limited the depth of their operations (Pryce 1778, 142).

William Warren's 1787 account is also informative because although it has to be seen in the context of the usual biases of a mine prospectus, within it he compares the Devon lodes with those of Cornwall. He claims that Dartmoor's mines, having been abandoned while still shallow 'nowhere above two fathoms below adit', still had the potential to be sunk to a similar depth as those in Cornwall, which he stated were from 40 to 70 fathoms. Bearing in mind that Devon tin at that time had not benefited from the knock-on effect of having deep copper mines, as had Cornwall (see Chapter 4), and were indeed still considered undeveloped, it only required the steady rise in the price of tin in the 1780s (Table 3.3) for adventurers such as Warren to re-evaluate the potential and speculate as to the depth of the lodes.

In 1795, the Rev John Swete also considered the potential riches which were still to be gained from Dartmoor's abandoned workings when he stated:

> *I am at a loss to conceive why, (wherever these Antient Stream works appear to have been rich) Adventures have not been formed, - and spirited searches made after the Parent Lode*
> (Gray 2000, 52)

Modern geological science confirms that Dartmoor, along with Bodmin Moor, had shallow tin lodes by comparison to other districts of the peninsula, together with only limited copper and silver-lead lodes (Chapter 3). Because the granite bosses of Dartmoor and Bodmin Moor were raised to higher altitude than other zones by the force of the magma, they were subject to far greater weathering, removing the upper sections of the tin lodes. This process in turn had provided the alluvial deposits which were exploited so successfully in the medieval period. However, it would not have been until the advent of deep mining and attempts to explore lodes at depth that their true character would be revealed.

The modern understanding of metalliferous geology only began to formulate in the early 19th century; prior to this time there was little discussion on the character of lodes other than the practical knowledge of mining men such as William Pryce (1778). Unfortunately, only the accounts of the literate are available for study, few of whom were at the frontline of mining operations; it is likely that the opinions of those more involved in the practical side of mining would be more relevant but were infrequently recorded. However, even Pryce claimed that the depth of the fissures that contained the metals, was potentially 'unlimited beyond the power of man to follow after', though he qualified this by stating that within these fissures, the best copper was found at between 40 and 80 fathoms and for tin between 20 and 60 fathoms (Pryce 1778, 79).

Seventeenth-century descriptions of mining in Devon (Anon 1671) and Cornwall (Ray 1674) do not question the potential or reliability of individual lodes at greater depth, and only describe the means of exploiting them, but at that time technology was insufficiently developed for the miners to have reason to worry whether lodes continued deeper than they had, up until that point, been able to exploit them.

In 1707, Heton had offered the following sentence among many other words of encouragement to those who might consider investing in mines:

> *As to the failing of veins and ores, ….it is a common observation that the bottoms of any fixed and settled veins of Lead, Copper and Co was hardly ever found ; and that where a Vein happens to be found, there are others not far from it.*
>
> (Heton 1707, Preface)

In 1799 one voice did express doubt as to Dartmoor's potential: John Taylor claimed that despite earlier profitability of surface working 'the lodes… of tin found in this district are not valuable enough, or do not continue to such depth as to make them very profitable' (Taylor 1799, 359). He reiterated this theme ten years later in 1810 when he noted that tin lodes in the granite [of Devon] are 'generally small and where they have of late been followed, not very productive', although he seemed more willing to accept that the district had some potential as, although the search for tin had mostly discontinued, 'the present high price may now in some degree revive it' (Risdon 1811, xiii). Taylor would later be joined by other informed doubters including Spargo, Tredinnick and others (see Chapter 4).

5.4.1 Frauds and scams

It is apparent that knowledgeable people of the day could distinguish between genuine mines and what De la Beche described as 'those which have merely been worked for the purpose of deceiving unwary adventurers' (De la Beche 1839, 325). In 1850, a note of caution was sounded to all those who might become involved in mine investment where reworking was involved:

> *Ask if the projected adventure is to be carried on in an old abandoned mine, or in one newly discovered; if old, be careful, "riches in sight" are seldom run away from…*
>
> (Bartlett 1850, 7)

What Bartlett was hinting at was that although re-worked abandoned mines were frequently operated successfully, they were often also adopted by adventurers operating on the margins of honest practice. Fraud was well-known in mining circles by the early 19th century. Mr Webb, an early 19th-century mine promoter, even warned against the 'notoriety of the various frauds, which have been practised on Gentlemen who become adventurers in mines' when himself attempting to raise interest in a series of tin mines in 1807 (DRO 1311M/Deeds/4/6).

Fraudulent mining enterprises in the Westcountry have been discussed at length elsewhere (Broughton 1971; Brooke 1980; Hall 2000). Both Brooke and Broughton included Dartmoor mines within their discussion, the latter providing many detailed, though largely unreferenced, anecdotes of the deceptive practices employed by mine adventurers to sell a mine to investors. Contemporary commentaries are also available, such as Hunt's account of Devon Burra Burra or 'Wheal Gatepost'. At this mine a gatepost was found to contain copper ore after being accidentally chipped by a passing cart, and a London-based company sprang up to exploit the site, which endured for only one season:

> *Thousands of pounds were – shall we say – mysteriously invested, in return for which the adventurers may look upon a dismantled engine house .. and a few heaps of stone…*
>
> (Hunt 1865, 30-1)

There is evidence that 'deceiving unwary adventurers', as De le Beche phrased it, was often practised under the cost-book system, whereby it was possible for a small nucleus of adventurers to take out a lease on a property with the sole intention of creating shares, which could be offloaded onto outside investors, thus, potentially, more profit could be made from selling shares than from selling ores. The operation would appear more credible if located at a site of previous activity, thus the tradition of reopening old men's tin workings and other abandoned mines was used to good effect. At copper mines other inducements were used such as the Wheal Gatepost example above, or in the case of both Holne Chase (*MJ* 02.07.1859), and Queen of the Dart (Hamilton Jenkin 1981, 101) where rich copper lodes were said to be visible in the beds of the adjacent River Dart. This practice, known as 'share-jobbing' or 'bal-selling' was particularly widespread in the two decades following 1850 (Barton 1968, 103). By 1865, Thomas Spargo, a mine engineer who was also a stock and share broker, vented his frustration on what he referred to as 'mining capitalists' who merely speculated without researching the enterprises they bought into, and that it was the losses incurred by such investors that had given mining a reputation as a hazardous financial prospect (Spargo 1865, 169).

Although detailed documentation is scarce, one example of dubious share dealing practice is the East Brookwood copper mine, launched in 1861, for which various documents, including a Cost Book, survive (CRO STA 1/25/1). The lease was held by William V Williams, who was also appointed Agent, and William Pavey. The company constituted 4096 shares which were divided between four in-adventurers (Table 5.1). At the company's first meeting the adventurers resolved to sell 2000 of these shares on the open market at 20 shillings per share, and awarded themselves 2096 shares free of the 20 shillings. In the years that followed, it is clear that at least three of the four parties had little commitment to the mine and rapidly offloaded their shares before the company inevitably got into difficulties and was wound up in 1869 (*MJ* 30.01.1869) having no recorded output of ore. At the end of three years, only 335 of the original 4096 shares remained in their possession, with Titherley, the last of the original adventures, holding these few. The others had disposed of theirs before the end of 1863.

Sanford is stated in the document as being a share broker, as was William V Williams, who had been involved in several similar small-scale, short-lived and unsuccessful mine adventures in the SE Dartmoor district in the 1850s and 60s. These including Caroline Wheal Prosper between 1854 and 1857 (Newman 2004b) and Devon Great Elizabeth 1857 to 1863, both of which were much criticized for being over-sold with their potential exaggerated, the latter having been described as having 'the greatest mineral

TABLE 5.1

Name	May 1861	Apr 1862	Jan 1863	Apr 1863	Jul 1863	Nov 1863	Sep 1864	Jul 1866
C Titherley	2996	541 (-2455)	281 (-260)	36 (-245)	84 (+48)	546 (+462)	540 (-6)	335(-205)
W V Williams	900	1026 (+226)	474 (-552)	384 (-90)	60 (-324)	- (-60)	-	-
J Williams	100	100	60 (-40)	60	0 (-60)	-	-	-
H Sanford	100	600 (+500)	420 (-180)	420	420	0 (-420)	-	-

Table 5.1 Showing the rapid movement of shares in East Brookwood Mine, following its launch in May 1861. Note that Titherley has 2996 shares including 996 of his own and 2000 for sale on the open marked. (Source: CRO STA 1/25/1)

wealth ever yet opened in England, if not the world' (*MJ* 24.09.1859). The East Brookwood company was in fact the second to work this particular site; its predecessor, Wrey Consols opened in 1856, also had Williams as the driving force (BI, Holne).

The inference of these dealings is supported by the character of the field evidence at East Brookwood mine which demonstrates that the site was barely developed during the years it was in work and suggests this was not an adventure that was entirely committed to the mining of copper. A short adit and one blocked shaft, together with a small spoil heap, indicative of limited underground activity remain at this site along with a large pumping wheelpit which apparently never had a leat built to divert water to it. At other mines where the field evidence and documentation conform with this model, including the examples cited above, there is evidence that once established, money would be expended on operations at the mine, but often on surface equipment rather than developing the mine underground. At Caroline Wheal Prosper, Holne Chase Mines (Fig 8.13) and Great Wheal Eleanor, extensive dressing floors were constructed and in the former two cases a tramway system with inclines was installed to transport the ore to them. In both cases, evidence of underground working is miniscule with short adits, shallow shafts and waste heaps commensurate with very limited exploration.

5.5 DISCUSSION

Mining culture after 1700 in the Westcountry was profoundly influenced by elements of its own tradition and custom. The low-capital operation of tin streamworks had provided an environment conducive to the establishment of 'free mining', wherein small-scale, low investment operations by groups of independent tinners could prosper. The tinners therefore had customary rights and traditions in place at an early date, which enabled the stannaries to remain independent of the crown with taxes payable on the products not on the mines. A uniquely local version of capitalism evolved from these practices of the medieval and post-medieval tinners whereby, for some, the investment of capital substituted for that of labour resulting in the acruing of a profit.

In the broader context of historical capitalism, the tin industry was less dependant on the 'commodity chain', as defined by Wallerstein, whereby everything, including raw materials, labour, capital and distribution networks, needed to be commodified for the system to function (Wallerstein 1995, 14). For some industries these chains were complex and were often, for historical reasons, incomplete (*Ibid* 15) and slower to develop a capital base as a result. However, tin working had the distinct advantage of being the first link in a chain supplying a highly restricted resource which, before the mid-18th century, was used to produce only one commodity and that was pewter. Thus a minimal number of links - essentially only dressing and smelting - were needed once the tin was dug out of the ground before the material was in the hands of the pewterors.

These two sets of conditions, ease of commodification and continuity of traditional practices, offer an explanation as to why the genesis of a capitalist system was in place so early in the stannaries. This system transferred, fairly unproblematically, to serve the very different economic requirements of hard rock mining from the 17th century onwards. By then, not only was capital essential for the development of mines but often the sums needed were so great that they had to be shared. Some elements of mine organization, such as the cost-book system and the organisation of labour, were developed versions of earlier practices and could be effectively adapted and applied to the mining of other metals including copper.

The traditions of the past and the apparent success of previous generations, as perceived by later promoters of mining, were also key to the investment of capital in, and continuation of, the mining industry in the late 18th and 19th century. The belief in the unfathomable depth of metallic ore and faith in new technology as the means to exploit them became primary factors in maintaining interest in mining and attracting investment, particularly from outside the district, enabling mine adventurers to raise the capital they needed to develop mines.

Promoting mines and selling shares in them was perceived as a means of importing prosperity into a district. It was in the interest of everyone involved in mining or residing in mining districts for the business to prosper, from the tutworkers, tributers and waged labourers, to the captains and agents. But also, mines were important to communities in which they were located where businesses could supply goods and services. Talking up the mining potential of an area or a specific mine, based on the exploits of the old men, was part of this tradition but also provided an opportunity for unscrupulous operators. In the case of mines where documentation providing details of the management is limited, there is a very indistinct line between mines that quickly failed as a result of fraudulent practice and those commenced on a more honest footing which were what Bartlett referred to as ‘the consequence of ill-directed labour, reckless expenditure, and unscientific research’ (Bartlett 1850, 2). In many cases however, field remains offer a more illuminating insight into the character, extent and endurance of individual mines and a collective analysis will provide more data as to how capitalists responded to the challenges set by Dartmoor. It is to field evidence that this discussion must now be directed.

CHAPTER SIX
THE ARCHAEOLOGICAL RESOURCE AND DATABASE: AN INTRODUCTION

6.1 STUDY AREA: LOCATION

Non-ferrous metal mining in Devon was confined mainly to the western half of the county, including Dartmoor, the Tamar valley and the Bere Ferrers peninsula, with small outlying districts at South Molton and Coombe Martin in north Devon. The most productive areas for copper and tin were the Tamar Valley and Dartmoor, both of which also produced lesser quantities of silver, lead and manganese. This study is concerned only with Dartmoor and examines field evidence from tin and copper mines, though occasional reference to the few silver-lead mines within the study area is necessary. The boundary of the study area coincides with that of Dartmoor National Park (DNP), a modern administrative boundary of little historical significance in this context. However, it does conveniently separate two contrasting landforms and marks the change from border country to hinterland and the lowlands of Devon. The high ground of the upland is dominated by the granite tors and steep folds of the river valleys. In lower lying pockets of the upland there are large bogs forming the sources of many of Devon's rivers and providing the important resource of water to the mining industry. Habitation on Dartmoor in the 18th and 19th centuries was confined to the river valleys, below 300m OD and comprised a mixture of isolated farmsteads and settlements, with mostly medieval and post-medieval origins. Much of the moorland was and still is made up of open commons. The border country on the lower slopes was, by 1700, fully enclosed farmland interspersed with small settlements, villages and towns while the steeper valley sides became occupied by deciduous woodland, much of whitch survives (Newman 2010). Geologically Dartmoor also represents a distinct mineralised zone whose character is governed by the existence of the granite boss and the Metamorphic Aureole (Chapter 3). For this reason it is usually considered separately to that of Devon's other important mining district in the Tamar valley, which is shared by the county of Cornwall.

6.1.1 Distribution (Fig 6.1)

Mines existed on many parts of Dartmoor, though spatially they are concentrated into certain zones, which are dependant on the richness of the mineralisation. Although tin streamworks are found on almost every river and stream valley of the upland and foothills, tin mines and openworks are more concentrated, being limited to the localities where workable lodes remained *in situ*. Copper, silver-lead and manganese mines are found only within the Metamorphic Aureole (see Chapter 3).

Dines (1956) divided Dartmoor into two mining zones placing the Tavistock area in with east Cornwall and central Dartmoor together with south-east Dartmoor and the Teign valley. Hamilton Jenkin (1974;

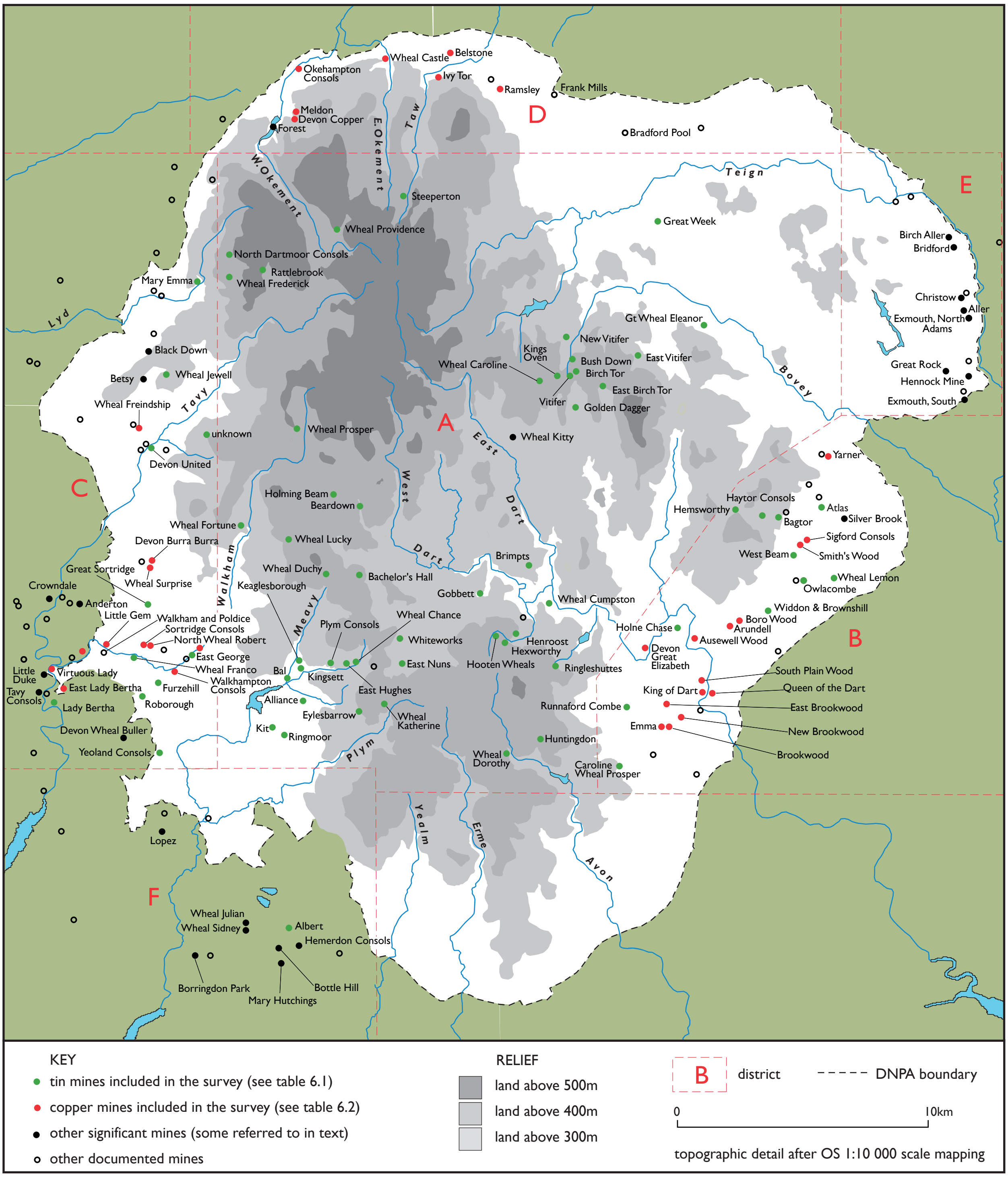


Fig 6.1 Distribution map showing the mines of Dartmoor and environs.

1981), by contrast, used many more districts, which probably owed more to convenience of description. Historically, only four mining districts existed on Dartmoor and these were based on the four Stannaries of Chagford, Plympton, Tavistock and Ashburton. These divisions were administrative districts which owe their origins solely to the medieval tin industry (Greeves 1992, 39-74) and do not reflect the spatiality of 18th and 19th century mining which was dictated solely by mineralisation of the metals.

In the following discussion, mining districts are defined by concentrations of mines within specific locales. These are:

1. The Central Upland
2. SE Dartmoor – Ashburton, Buckfastleigh and Ilsington
3. Western Dartmoor – Mary Tavy to Horrabridge
4. Okehampton and Northern Dartmoor
5. The Teign Valley
6. Plympton and SW Dartmoor

Of these, the emphasis of the fieldwork has been on 1 to 4. Systematic fieldwork has not been carried out in the Teign valley – this area is dominated by lead mines which fall outside the scope of this study – and Plympton which lies mostly outside of the national park. These areas are not included in the statistics or the site tables, although the documented mines are listed in the appendix.

6.2 THE MINES INCLUDED IN THE STUDY

As a result of the step-one desktop trawl described in section 2.3.2, from an initial total of 535 documented mining concerns within the part of Devon where Dartmoor is located, 435 were selected as being within the study area (see Appendix). Both the above figures are known to be non-exhaustive and would certainly be expanded by future research. Within the confines of the study area there are at least 104 mines that can be considered as archaeological sites for the documented period 1700 – 1914, which make up the sample for this thesis. Of these mines, 61 are sites that also have evidence for mining activity prior to the study period. In terms of the various ores worked, at least 68 out of the 104 archaeological sites were worked mainly for tin (Table 6.1) and 35 worked mainly copper (Table 6.2). Of that total eight mines can be considered mixture mines where more than one metal was exploited commercially or prospected for, including in some cases silver-lead. These proportions should be considered only a rough guide however, based on information from a variety of secondary sources including Dines (1956), Hamilton Jenkin (1974; 1981) and other published accounts, which themselves were compilations of data from not wholly reliable sources. Of the total mines recorded as part of the field and documentary research, only a limited number have been selected for detailed discussion and the data is set out in tables elsewhere (Chapter 7-9). Each mine or company name known through documentary data has an individual mine number in the appendix and for each site where archaeological evidence has been recorded in tables 6.1 and 6.2, a site number has also been assigned. As most sites are likely to have had different names over time, a primary site name has been selected for each which is used throughout the text and in all tables; in most cases this is the name that the site in question is most usually known by.

TABLE 6.1 Mines included in the survey which were worked mainly for tin and possess field evidence

Column A= site number; column B = site category; column C = level of survey (grey shaded rows = no field recording by PN)

Name	A	NGR (SX)	B	C	Old Men's Working	Surface Evidence of Underground Activity	Spoil Heaps	Large Wheelpit	Flatrod System	Horse Whim	Dressing Floor	Burning House	Engine House
Albert, Wheal	2	5680 5955	DP	3	PW; SW	BS; BA	SC(l)	-	-	HW45	-	-	-
Alliance	108	5761 6878	P	0	PW	-		-	-	-	-	-	-
Atlas	3	7810 7655	DP	0+3	-	BS; BA	AFD(l)	WP2	-	-	DF5	BH1	EH30
Bachelors Hall	8	5975 7330	SS	1	PW	BS; BA	SC(s)	-	FR30	HW41	DF64;66;70;76	-	-
Bal	10	5682 6917	DP	1	PW;OW	BS	SC(s)	-	-	-	DF33	-	-
Beam, West	109	7655 7335	LS	1	OW	BS	SC(l,m)	-	-	-	DF77	BH11	EH27; 28; 29
Beardown	11	5975 7630	DP	3	PW	BS; BA	SC(s); AFD(s)	-	FR12	-	DF32	-	-
Bertha, Lady	71	4710 6890	SS	1	U	BS	DW(l); FD(l)	WP18; 19; 46	-	-	DF18	-	-
Birch Tor and Vitifer	12	6850 8150	LS	2	OW	BS; BA	SC(l); UD(l)	WP1-4	FR6; 14	HW20,30,42,43,44	DF16; 17	-	-
Birch Tor, East	24	6935 8100	SS	2	OW	BS; BA	SC(l,m)	WP34; 35	-	-	DF61; 62	-	-
Brimpts	15	6600 7400	SS	1	PW; OW	BS	-	WP45	FR25; 28; 29	HW4	DF54, 55; 73	-	-
Bush Down	77	6820 8190	P	2	OW	OA	AFD x1	-	-	-	-	-	-
Caroline, Wheal	79	6680 8117	DP	2	PW	BS; BA	SFD x 1	WP16	FR11	HW9	DF12	-	-
Chance, Wheal	20	5950 7000	DP	2	PW	BS; BA	SC	-	-	HW8	DF11	-	-
Combeshead	102	5849 6840	DP	2	PW; OW	BA	-	-	-	-	DF68	-	-
Cumpston, Wheal	22	6720 7210	DP	1	PW	BS; BA	-	-	-	-	DF52	-	-
Curbeam	91	5620 8450	DP	2	OW	-	-	-	-	-	-	-	-
Devon United	106	5155 7875	LS	1	-	OS; BA	SC(l); DW(l)	WP48; 50	FR36	-	DF75	BH5 & 6	-
Dorothy, Wheal	78	6552 6640	P	1	PW	BS	SC(s)	-	-	-	DF6	-	-
Duchy, Wheal	76	5850 7359	P	1	OW	BS	SC(s)	-	-	HW17	-	-	-
Eleanor, Great Wheal	25	7350 8340	DP	1	OW	BS; BA	AFD(l)	WP27	FR27	-	DF35	-	EH13
Eylesbarrow	1	5980 6825	LS	2-3	PW; OW	BS; OA; BA	SC (l,m)	WP29; 30	FR1; 8; 10; 26	HW34-9	DF41-6	-	-
Fortune, Wheal	29	5500 7550	SS	3	PW	BS; BA	SC(s)	WP32	FR38	-	DF25-7	-	-
Frederick, Wheal	31	5458 8538	DP	3	SW	-	-	-	-	-	DF51	-	-

TABLE 6.1 (cont)

Furzehill	32	5180 6920	SS	1	PW; OW	BS	SC(s); UD(l)	not found	-	HW27, 28	DF59	BH4	-
Gem, Little	74	7055 4948	SS	1	-	BS; BA	AFD(l)	WP41	-		DF36	BH3	-
Gibbet (Hill)	96	5030 8090	DP	1	-	BS	SC(l) x 2	WP31	-	HW25; 32	-	-	-
Gobbett	33	6470 7280	SS	1	OW	BS; OA	-	-	-	-	DF22	-	-
Golden Dagger	34	6830 8020	SS	2	OW	BS; OS, BA	SFD(l)	WP40	-	-	DF19; 20	-	-
Haytor Consols	9	7530 7550	SS	1+2	OW	BS; OA	SFD(l); SC(s)	WP47	FR16	HW23,24,46	DF56; 57	-	-
Hexworthy	35	6560 7090	LS	2+3	OW	BS	SFD(l); DW(l)	WP13	FR20; 21	HW6	DF7,8	-	-
Holming Beam	36	5880 7680	DP	1	PW	BS	-	-	-		-	-	-
Holne Chase	37	7230 7145	DP	3	OW	OS; OA	SFD(s)	-	-	HW7	DF9	-	-
Hughes, East	39	5931 6995	DP	3	PW; OW	BS	-	-	-	-	DF14	-	-
Huntingdon	7	6680 6700	SS	3	PW	BS; BA	SC	WP42	FR17	HW40	DF29	-	-
Jewell, Wheal (Huel)	85	5230 8140	SS	1	PW	BS; BA	destroyed	WP26	FR31	HW22	-	-	-
Katherine, Wheal	41	6070 6830	SS	2+3	OW	BS	SC (s,l,m)	WP33	-	-	DF40	-	-
Keaglesborough	42	5731 7003	DP	3	OW	BS; OA	SC(s)	-	-	-	DF23; DF24	-	-
King's Oven	44	6750 8130	P	2	OW	-	-	-	-	-	-	-	-
Kingset	45	5776 6980	DP	2	OW	-	-	-	-	-	DF34	-	-
Kit	99	5628 6745	DP	1	-	-	-	-	-	-	DF63	-	-
Kitty	101	65-- 79--		0	?	-	-	-		-	-	-	-
Lemon, Wheal	48	7820 7350	P	1	PW	OA		-	-	-	-	-	-
Lucky, Wheal	75	5720 7480	DP	1	PW; OW	BS; OA		-	-	HW18	-	-	-
Mary Emma, Wheal	49	5325 8316	DP	3	PW; OW	BS; BA	SFD; AFD	-	FR13	-	DF50	-	-
Nuns, East	51	6150 7010	DP	1	PW	-	-	-	-	-	DF47	-	-
Owlacombe	98	7700 7350	LS	0	OW	-		-		-	-	BH8	EH26
Plym Consols	52	5850 6984	DP	2	OW	BS	SC(s)	WP15	FR32	-	-	-	-
Prosper, Caroline Wheal	53	7015 6586	DP	3	OW	-	AFD(l);SC(s)	WP17	FR2	-	DF15	-	-
Prosper, Wheal	54	5740 7930	DP	3	PW; OW	BS; BA	SC(s)	-	-	-	DF53	-	-
Providence, Wheal	55	5885 8730	P	1	SW	-	-	-	-	-	-	-	-
Rattlebrook	4	5585 8570	DP	1	OW	BS	SC(s)	-	-	-	DF49	-	-
Ringleshutes	57	6750 6980	DP	2	PW; OW	BS; BA	SFD(l)	-	-	-	DF10	-	EH4
Ringmoor Down	58	5679 6719	DP	2	-	-	-	-	-	-	DF69	-	-
Robert, North Wheal	90	5130 7080	LS	0+1	OW	-	UD(l)	-	?	-	-	-	EH20

TABLE 6.1 (cont)

Roborough Down, North	64	5131 6856	DP	1	PW; OW	-	-	-	-	-	DF37	-	-
Runnaford Combe	21	7015 6811	DP	1	OW	BS	-	?	-	-	-	-	EH14
Sigford Consols	60	7730 7520	DP	1	-	OS; BS; OA	-	-	-	-	-	-	EH9
Smith's Wood	62	7730 7480	DP	1	-	BS	dispersed	WP43	FR9	-	-	BH2	-
Sortridge, Great	70	5110 7240	DP	2	PW	BS	SC(s,m)	-	-	-	-	-	-
Steeperton	47	6130 8820	DP	3	OW	BS; BA	AFD(s,m)	-	-	-	DF13	-	-
Vitifer Consols, New	65	6790 6280	DP	3	OW	BS; BA	SC(s); AFD(s,m)	see DF48	FR33	HW26	DF48	-	-
Vitifer, East	63	7088 7238	SS	1	OW	BS; OS; BA	AFD(s)	see DF38	-	-	DF38	-	-
Walkham United	73	4896 7067	SS	1	AD	BS; OA	SFD(l); UD(l)	see DF21	FR4	-	DF21	-	-
Week Consols, Great	88	7132 8750	DP	1	OW	-	dispersed	destroyed	-	-	destroyed	-	-
Whiddon	66	7560 7215	SS	0	PW	BS; BA		-	-	-		BH9	-
White Works (Great)	40	6140 7100	LS	3	PW; OW	BS; BA	SC(l); AFD	not found	-	HW14,15,16	DF28; 60; 65	-	-
Willsworthy	112	5485 8091	P	1	PW	OA	-	-	-	-	-	-	-
Yeoland Consols	67	5140 6630	LS	0	PW	OS; BS; OA	-	-	-	-	DF67	BH10	EH25

SPOIL HEAPS
AFD = adit finger dump
SFD = shaft finger dump
SC = shaft collar
DW = dressing waste
UD = unstructured dump

OLD MENS WORKING (ie assumed pre-1700)
OW = openwork
PW = pit working
SW = streamwork
A =adit
U = uncertain

SITE CATEGORY
P = prospect
DP = developed prospect
SS = small-scale productive site
LS = large-scale productive site

UNDERGROUND SURFACE EVIDENCE
BS = blocked shaft
BA = blocked adit
OS = open shaft
OA = open adit

In brackets
s = small; l = large; m = multi

Names and reference numbers used in Tables 6.1 and 6.2 are the primary site references. For alternative documented names, parish and bibliographical references see APPENDIX. Dates are not included on this table or in Appendix A: firstly because earliest dates cannot be assigned with any certainty from documentation, and secondly, because the majority of mines were worked on more than one occasion, it is not possible to be consistent or accurate for the whole sample. However, where dating is relevant, documented events are referred to in the field evidence sections (Chapter 7- 9) and within the historical context (Chapter 4 and 5)

TABLE 6.2 Mines included in the survey worked mainly for copper and possessing field evidence

Column A = site number; B = site category; C = level of survey (Names and reference numbers used in this list are the primary site references. For alternative documented names refer to Appendix A)

Name of Mine	A	NGR (SX)	B	C	D	Surface Evidence of UG Activity	Spoil Heaps	Large Wheelpit	Flatrod System (FR)	Horse Whim	Dressing Floor	Crusher House	Engine House
Arundell United	5	7445 7160	DP	3	-	OS; BS	UD	WP1	-	-	-	CH4	EH5
Ausewell	6	7270 7090	SS	3	OW	BA; OW	UD	-	-	-	DF1, 2, 3, 4	-	-
Belstone Consols	83	6320 9450	SS	1	-	BS	UD	WP24	FR19	-	-	-	-
Bertha, East Lady	80	4775 6903	DP	1	-	BA; BS	-	-	-	-	DF31	-	EH16
Betsy, Wheal	86	5100 8150	LS	0+1	-	BS	UD	-	-	-	-	-	EH1; EH17
Blackpool, Wheal	13	730- 684-	P	1	-	OA	-	-	-	-	-	-	-
Boro Wood	14	7478 7158	P	2	-	OS; OA	-	-	-	HW47	-	-	-
Brookwood	16	7180 6755	LS	3	-	OS	SFD(l,m)	WP6,7,8,9	FR18	HW3	-	CH1; CH3	EH6; EH7
Brookwood, East	17	7180 6840	P	1	OW	OA; BS	AFD(s)	WP3	FR22	HW1	-	-	-
Brookwood, New	18	7236 6790	P	1	-	OA	AFD(l)	-	-	HW2	-	-	EH15
Burra Burra, Devon	94	5140 7415	DP	0	-	-	-	-	-	-	-	-	EH24
Castle, Wheal	19	607- 943-	P	1	-	BS	-	-	-	-	-	-	-
Devon Copper	68	5701 9177	P	3	OW	BS; BA	AFT; SC	WP14	FR35	-	-	-	-
Elizabeth, Devon Great	26	7093 7073	P	1	-	BS	-	WP4	-	-	-	-	-
Emma, Wheal	16	7150 6750	LS	3	-	OS; OA; BS; BA	SFD(l); SC(l); UD(l)	WP10,11,12	FR7; FR15	HW4, 5	-	-	-
George, (East) Wheal	69	5295 7040	DP	1	-	BS	SC(s)	not found	-	-	-	-	-
Ivytor (Ivy Tor)	84	6270 9350	DP	1	OW	OA;BS	UD	WP21	-	-	-	-	-
King of the Dart	43	7338 6885	P	2	-	OA	-	-	-	-	-	-	-
Kitts	100	5165 8455	DP	1	-	OA; BS	-	-	-	-	-	-	-
Knight of the Dart	46	7301 6850	P	2	-	OA	-	-	-	-	-	-	-
Meldon	114	564- 920-	P	3	-	BA	-	-	-	-	-	-	-
Okehampton Consols	92	5710 9350	DP	0+2	-	BS; OA	AFD(s)	-	-	-	-	-	-
Queen of the Dart	56	7345 6882	DP	2	-	BS	UD(l)	-	-	-	-	-	-
Ramsley (Hill)	28	6500 9300	LS	1	-	BS	SFD(l, m)	WP28	-	-	DF4	CH7	EH19
Rose, Wheal	59	5230 6970	DP	1	-	BS	-	-	-	HW13	-	-	-
Silverbrook	61	7890 7583	SS	1	-	BS	UD; SC(s)	-	-	HW10	-	CH6	EH10
Sortridge Consols	93	5100 7060	LS	1	PW	BS; BA	SFD(l,m)	destroyed	-	-	DF58	-	-
South Plain Wood	38	7330 6950	P	1	PW	OS; OA	SC(s)	not found	FR23	HW11	-	-	-
Surprise, Wheal	82	5115 7400	DP	1	-	BS	SC(s)	WP20	-	HW19; HW20	-	-	-
Torwood	87	5365 8908	P	1	-	BS	AFD(s)	-	-	-	-	-	-
Treeby, Wheal	104	710- 672-	P	3	-	OA	AFD(s)	-	-	-	-	-	-
unknown (Cudlippton Down)	113	5289 7842	P	1	-	BS, BA	AFD(l); SC(s)	WP53	-	HW48	-	-	-
Virtuous Lady	81	4730 6980	LS	1	PW	OS; OA; BS; BA	UD(l)	WP22; WP23	FR24	HW21	DF30	CH2	-
Yarner	30	7830 7830	SS	1	-	BS	UD(l)	destroyed	-	HW12	-	CH8	EH12
Yennadon	103	5420 6835	P	0	-	-	-	-	-	-	-	-	-

SPOIL HEAPS
AFD = adit finger dump
SFD = shaft finger dump
SC = shaft collar
UD = unstructured dump
In brackets s = small; l = large; m = multi

OLD MENS WORKING (ie assumed pre-1700)
OW = openwork
PW = pit working
SW = streamwork
A =adit

SITE CATEGORY
P = prospect
DP = developed prospect
SS = small-scale productive site
LS = large-scale productive site

UNDERGROUND SURFACE EVIDENCE
BS = blocked shaft
BA = blocked adit
OS = open shaft
OA = open adit

6.2.1 Categories of mines (Table 6.3)

Although ordering individual classes of field evidence into a database is mostly straightforward, the combinations of remains that make up the totality of an individual mine, or complete 'systems', are each unique, so organizing them on the basis of similarity and difference is fraught with problems. Instead, the following categories are intended to reflect the probable stage of development of mine sites at the point of abandonment based on the extent of their surface remains rather than any similarities in the type of features present. In many examples this division is likely also to reflect the duration and relative success of the operations, associated with the remains. The assessment does not include any evidence that is of a pre-1700 character.

Prospect (Type 1)

Where there is some but very little surface evidence of prospecting, i.e. one or more very short adits and/or evidence of shallow shafts. These sites will have little or no waste associated and there will be no evidence of ore dressing, pumping or other infrastructure. Sites in this category may be both documented or undocumented.

Developed Prospect (Type 2)

These sites will be similar to a prospect though with some evidence of a more serious attempt at underground exploration and associated surface features such as dressing, tramming, pumping or infrastructure though on a small scale. These sites are likely to have little or no recorded output.

Small scale productive mine (Type 3)

Sites that have clearly produced some ore, judging by the size of waste heaps or quantities of tailings, but are still relatively undeveloped and modest in scale. All the necessary equipment would have been present, such as pumping, dressing, tramming etc

Large scale productive mine (Type 4)

Sites, which field evidence has established, once supported productive and probably multiple enduring enterprises. Such sites will have evidence of extensive underground activity, large spoil heaps, many shafts, well developed dressing floors and dressing waste.

The terms 'large-scale' and 'small-scale' are relative and in this instance apply to field remains of mines within the study area only. No comparison should be made with mine sites in other mining districts. No inference of actual output should be taken from the word 'productive'.

TABLE 6.3

Ore	Type 1	Type 2	Type 3	Type 4	Total
Tin (Sn)	8	35	16	9	68
Copper (Cu)	15	10	4	6	35
Mixture(Sn/Pb/Cu/Au)	1	0	1	6	8

Mines within the Dartmoor study area, for which archaeological evidence has been noted together with ores worked. Nb this table only includes data from the four districts described above

6.2.1 Field Evidence (Table 6.4)

The material evidence of mining within the limitations of this thesis is restricted to the primary surface evidence of mining from lode sources and ore dressing but includes associated water supplies and evidence for the movement of material and waste. In the following three chapters data is presented thematically and split between the two headings of extractive elements (Chapter 6) and non extractive elements (Chapter 7). Only surface remains are described, no underground investigation has been undertaken, though the underground implications of some aspects of the surface remains are explored. Table 6.4 sets out the operations involved in mining and lists the types of field remains associated with each operation.

Reference to field evidence in the text

Names of mines used in the following chapters correspond with the Primary Site Reference in the database. See the appendix for further details and precise locations. Where individual elements of mines are referred to, abbreviations are used within brackets that correspond to the tables containing this data. Sources for dates associated with these items, described in the text are listed in the tables. Table 7.1 large waterwheel pits (abbr. WP); Table 7.2 water-powered pumping systems – i.e. flat-rods (abbr. FR); Table 7.3 engine houses, (abbr. EH); Table 7.4 horse whims (abbr. HW); Table 8.1 stamping mills/dressing floors (abbr. DF); Table 8.2 burning houses (abbr. BH); Table 8.3 crusher houses (abbr. CH); Table 9.1 leats (abbr. L).

TABLE 6.4
Categories of field evidence: summary

Category	Operation	Term	Surface evidence	Associated Features/ term	Additional associated terms*
Prospecting	Searching for lodes	Prospecting pit	Earthwork	Spoil heap	Costean pit/ shode pit
	Proving lodes	Trial adit	Rock cut feature/earthwork	Spoil heap	Portal
Extraction	Working lodes from surface	Openwork	Rock cut feature/ earthwork	Prospecting pit/ leat/ reservoir	Beamwork/ Gert
(pre-1700)	“	Pit working	Earthwork	Prospecting pit/ spoil heap	‘Lodeback pit’
Extraction	Vertical underground access	Shaft	Earthwork	Spoil heap	Stope
(post 1700)	Horizontal underground access	Adit	Rock cut feature/earthwork	Spoil heap/ tramway	Portal
	Power to pumping system	Wheelpit	Ruined structure	Flat rod channel/ leat	Tailrace/ launder
	Supply of water power	Leat	Earthwork	Reservoir/ wheelpit	Headwier/ sluice/ launder
	Storage of water	Reservoir	Earthwork	Leat	Sluice/ dam
	Transmission of power	Flat rod channel	Earthwork	Bob pit/ wheelpit	Support posts
	“	Bob pit	Ruined structure	Shaft/ flat rod channel	Counterweight chamber
	Power to pumping system (steam)	Pumping engine house	Ruined building	Bob pit	Boiler house/chimney/shaft
	Hoisting in shafts (horse powered)	Horse whim	Earthwork	Shaft	Mellior/Plat
	Hoisting in shafts (water powered)	Wheelpit	Ruined structure	drum pit	Tailrace/ launder
	Hoisting in shafts (steam powered)	Whim engine house	Ruined building	Shaft	Boiler house/ flywheel pit
	Hoisting in shafts (man powered)	Capstan	Earthwork	Shaft	
	Disposal of waste	Spoil heap	Earthwork	Whim/ tramway/ shaft/ adit	Deads
Dressing	Stamping	Stamping mill	Ruined structure	Wheelpit/ leat/ engine house	Stamps area/ slime tank
	Power to stamping mill (water)	Wheelpit	Ruined structure	Stamping mill/ leat/ dressing floor	Launder/ tailrace
	Power to stamping mill (steam)	Stamping engine house	Ruined building	Stamping mill/ dressing floor	Boiler house
	Supply of water	Leat	Earthwork	Reservoir/ wheelpit/ dressing floor	Launder/ headweir/ sluice
	Storage of water	Reservoir	Earthwork	Leat	Sluice
	Cobbing	Cobbing floor	Earthwork/ ruined structure	Spoil heap	
	Crushing	Crusher house	Ruined building	Wheelpit/ leat	Engine house
	Dressing	Dressing floor	Ruined building/earthwork	Stamping mill/ leat/ dressing waste/ tramway/ buddle	
	Concentrating	Buddle	Earthwork/ruined structure	Dressing floor/ stamping mill	Round buddle/ rect. buddle
	Disposal of waste	Tailings pit	Earthwork	Stamping mill/ buddles/ dressing floor	Slimes/ dam
	Calcining	Reverberatory Calciner	Ruined building	Flue/ chimney	Burning house
	“	Brunton Calciner	Ruined building	Flue/ labyrinth/ water wheel	Arsenic flue
Movement	Movement of ore and waste	Tramway	Earthwork	Spoil heap/ Incline	Sleeper imprints
	“	Incline	Earthwork	Horse whim/tramway	
	Movement of materials and people to and from the mine	Mine track	Earthwork		

Table 6.4 showing the main categories and types of archaeological remains associated with the extraction and processing of metallic ores on Dartmoor, as recorded through field investigation and survey.

CHAPTER SEVEN
THE SURFACE EVIDENCE OF LODE EXTRACTION

7.1 THE WORKING OF METALLIC LODES BEFORE 1700

7.1.1 Tin

The discovery and early exploitation of tin lodes in south-west Britain represented a significant advance in the tinners' understanding of metalliferous geology; it demanded major changes to the working methodology and application of technology and seeded organisational changes which would eventually develop into the capitalized system of mine adventure that characterized the mining industry in the 18th to 20th centuries, discussed in Chapter 5. However, the origin of working tin lodes is obscure. Neither Greeves (1981; 1981a) nor Gerrard (1994; 1996; 2000), in their respective studies of Devon or Cornwall's earlier tin industries, were able to suggest precisely when the attention of the tinners was first drawn to the lodes, although Greeves used the term 'logical progression' when referring to the working of the two types of deposit, suggesting the precedence of streamworking over lode working (Greeves 1981a, 89). The same author also identified early examples of documented lode workings such as 'Joys Beam' in 1511, which he suggested provide inferential evidence that lode working was established by the 15th century on Dartmoor, 'beam' being a term which referred to lode works rather than streamworks (Greeves 1981, 142). These assertions offer substance to those of earlier writers such as Lewis (1908, 3), who considered that due to the richness and low capital needs of alluvial streamworking, little attention was paid to the lodes until the streamworks showed signs of exhaustion, an event which Hatcher assumes to have been in the mid 15th century (Hatcher 1973, 46). In 1584 John Norden, a Cornish topographer, explained very clearly how the differences between lode and stream tin were perceived in terms of practicality of working:

> *..the workes and maner of workes are of two sortes, Streame works and Loade workes. The Streame works are in the brookes, in valleys among the hills: The Loade workes in the mountaynes. The Streame workes are shallowe and more easie: The Loade workes deepe, paynfull and daungerous*
> (Norden 1584, 13)

Under these circumstances the progression, from working the easily accessible alluvial deposits to the more labour intensive lodes, would indeed seem logical, and is a behaviour frequently witnessed in other parts of the world, particularly in gold producing areas, where rich placer deposits are worked in an initial frenzy of activity, leaving hard rock deposits to be worked only after the former become exhausted (see Safford 2004).

However, some streamworking continued on Dartmoor into the 18th century (Chapter 4), and it is more likely that the transfer of attention to tin lodes occurred at a very localized level; when individual alluvial deposits became exhausted, working of associated lodes would then be considered worthwhile. The

Fig 7.1 The interior of a rock-cut openwork at Ausewell Wood.

transition from alluvial to lode tin deposits for the whole of Dartmoor and the southwest region may have been slow rather than a chronologically precise epoch but the working of lodes was established as the major focus of extractive effort by the commencement of the study period in 1700.

7.1.2 Copper and silver-lead

It has been argued above (Chapter 4) that copper was not worked commercially in Devon before the late 17th century and reliable documented examples of copper mines on Dartmoor are yet to come to light from before 1700. Of the eight Devon copper mines described as working or abandoned by Kalmeter in 1724 (Table 4.1), three were on the peripheries of Dartmoor, including Virtuous Lady and Ausewell. The latter is of particular interest, where a series of deep, rock-cut openworks (Fig 7.1), indicative of a shallow lode, were well developed at the time of Kalmeter's visit and could have origins prior to 1700. Surface workings of this type are unusual for copper, which more often occurs at much greater depth, and this site must be considered atypical, as the majority of copper mines were worked using normal underground methods. Lead and silver mines, despite having origins in the 13th century in the Bere Ferrers area (Claughton 1996, 35), were also undeveloped on Dartmoor before 1700, although many of the mines recorded by Kalmeter were by tradition at the time 'ancient', including the Black Down lead mines, which the miners informed him were Elizabethan in origin (Brooke 2001, 10). Although a probable exaggeration, this does suggest that these mines were worked before living memory in 1724, in which case shafts would have been needed to work them at the required depth. It is not yet possible to identify field evidence of a distinctly early date with confidence but by the start of the study period, underground working for all of Dartmoor's non-ferrous metals was certainly a normal practice.

7.1.3 Terminology

The field evidence for lode extraction, survives in four major categories:

1. Prospecting – pits excavated during the search for lodes
2. Openworks or beamworks – a type of opencast working
3. Primary shaft workings or 'pit workings' - a form of early shaft used specifically on tin lodes. More recently the term 'lodeback pit' has been coined (Gerrard 2000, 81)
4. Mines – deep underground workings served by shafts, adits, pumping and hoisting equipment. May date to the period before and after 1700.

Although in general usage the terms 'mine' and 'mining' may be applied to all forms of mineral extraction, in the following discussion these terms apply only to category 4.

7.1.4 Prospecting

Historical evidence

Techniques for the discovery of tin lodes were written down from an early date. Carew in 1602, for example, refers to the practice of digging pits in search of 'shoad' or 'shode' (small pieces of detached ore) as a means of tracing metalliferous lodes. Borlase and Pryce both described a similar method in the later 18th century in Cornwall (Borlase 1758, 166; Pryce 1778, 127), but the following more detailed description covers Cornwall and Devon in 1671 by an anonymous writer.

After searching for promising locations using methods, which rely heavily on observation and a familiarity with certain phenomena in the landscape, the prospector would hopefully find pieces of 'shoad', then proceeded to dig a series of pits:

> *For in the next place we sink down about the foot or bottom of the Hill an essay hatch (an orifice made for the search of the vein, about 6 foot long and four foot broad)….*
>
> *6. Albeit we find no Shoad in this first Hatch, …. We are not (as yet) altogether discouraged but ascend commonly about 12 fathom, and sink a 2d Hatch, as the former: And in case none appear in this, we go then as many fathom on each hand at the same height, and sink there as before, and so ascend proportionately with 3 or more Hatches as it were in brest, till we come to the top of the Hill, and if we find none in any of these Hatches, then farewell to that Hill*
>
> (Anon 1671, 2099-100).

This practice of 'shoding' had changed little in Pryce's description 107 years later, although he does make the following comment:

> *It is much to be lamented that the science of Shoding is greatly lost in the present age. Among our Miners we have not fifty, who scientifically or experimentally understand anything of the matter*
>
> (Pryce 1778, 126).

If, as this passage strongly suggests, these skills were in decline, then searching for virgin tin lodes from the surface was becoming less common in the 1770s and this would be because deeper lodes were being sought using advanced methods (below). Alternatively, and perhaps more likely, the mainly deeper mining, which was the norm by that time, was occurring on known lodes referred to as 'old men's' or 'ancient' workings; these had originally been worked only to a shallow depth from surface but to later miners, their presence suggested greater potential at depth, the implications of which have been discussed in Chapter 5.

Pryce also describes a separate method known as 'Costeening', by which pits of between 6ft and 12ft deep were sunk down to the 'fast or solid country …and driving from one to another across the direction of the vein' (Pryce 1778, 124). In other words interconnecting horizontal tunnels or 'drifts' were driven between the pits at 90º to the locally dominant orientation of the lodes, which would hopefully confirm their presence. According to a writer of 1857, this was a method complementary to shoding, which would identify the precise location and strike of the lode (Scoffern 1857, 85). Unlike other techniques described, costeaning was still in use in the 19th century and frequently mentioned in mine Captains' reports. In 1856 two lodes were reported revealed at Huckworthy Bridge Copper Mine by this method (BI, Walkhampton) and in 1848 tin lodes were revealed at Whiddon Mine by costeaning (*MJ* 15.07.1848). Together with several other documentary occurrences, these examples confirm that this term, if not the precise practice, was still in use in the mid-19th century.

The methods involved in the discovery of non-ferrous metals other than tin are, by comparison, poorly described by contemporary Westcountry writers. Unlike tin, copper 'shoad' or 'shode' becomes detached from the lode less frequently, as noted by William Borlase in 1758: 'Copper lodes throw from them few shodes, so that they are not often accessory to their own discovery'.

Pryce (1778, 126) makes a similar statement, but both writers concede that copper shodes do occur sufficiently often to make the use of costeaning or prospecting pits worthwhile on the occasions that they do. Other clues at surface indicating the possible presence of lodes were also available to the prospectors. Borlase describes copper lodes being visible in eroded cliffs for example and he cites the observation of a 'gossan', 'an earthy ochrous stone, ruddy and crumbling, like the rust of iron' which he claims was a 'promising symptom' for the presence of copper. Pryce also used several pages to extol the virtues of the *Virgula Divinatoria* or divining rod, which, he claimed, was effective (Pryce 1778, 116).

These methods used by the earlier tin and copper miners relied on the lodes outcropping on the surface of the country rock. Although the majority of mines exploited lodes in areas where the surface had already been broken by the old men, such methods were not effective for copper or tin lodes where they occurred at greater depth, as would have been sought later in the study period, where no hint for the presence of the lode was visible at surface. However, Pryce also described two methods that could be used in this scenario. For one of these he suggests cutting a north to south drift (deep trench) across the surface of the ground, which will expose any lodes in its path. Again only lodes that had relatively shallow backs would be thus discovered. The second, similar method, involved driving an adit or tunnel (see below) north or south across the course of suspected lodes.

According to Buckley (2005, 84), an increase in the discovery of copper lodes in Cornwall, when that industry burgeoned in the early 18th century, occurred because tin mines were by then being sunk deeper and copper became more plentiful at depth. Kalmeter, when describing the Camborne, Redruth area of Cornwall, also mentioned that many of the operational copper mines at the time of his visit (1722-4) had originally been worked for tin (Brooke 2001, 36-9). This is unlikely to have been the case in the Dartmoor district where, during the same period, Kalmeter noted that the very few tin mines in work, such as Whiddon at only 18ftms deep, would have fallen far short of those in the Camborne district. Also, few tin mines on Dartmoor were developed into copper mines.

Field evidence

Tin prospecting or trial pits on Dartmoor have been described elsewhere by Gerrard (2000, 26) and Newman (2006a, 133). Gerrard has however, interpreted the techniques of shoding and costeening to be one and the same which is not followed here after re-appraisal of the documentary sources strongly suggests that these were separate techniques, although the difference in the appearance of the field remains between these two may be difficult to differentiate. In the descriptions available, both consisted of small pits running across the alignments of the lodes. The anonymous account of 1671 claimed the shode pits were sunk 12fm (22m) apart, but no such information accompanies Pryce's description of costeening. There is every possibility that pits sunk for both purposes occur together and, where successful, they may be interspersed with examples of the extractive pit workings described below.

There is however a great volume of field evidence that may be identified as that of prospecting pits. They comprise small circular or elliptical earthwork pits, usually 2-3m diameter, with a conical profile often heavily silted or water-filled and reedy. They have a small crescentic spoil heap on the lower (downhill) side representing material unearthed and demonstrating limited depth; they are arranged in lines or linear clusters. These pits are very common at tin extraction sites on Dartmoor, especially on the granite zone, but also any place where tin lodes have been exploited or searched for. There are also many examples that are isolated, not associated with evidence of actual exploitation which were clearly unsuccessful trials (Fig 7.2; 7.3). As yet no date has been established for any trial pits, but where present at mines that have been the subject of earthwork surveys, their relative date can be established when associated with other features. At Huntingdon for example (Fig 7.4) the linear cluster of smaller prospecting pits has been transected by an alignment of undocumented pit workings and shafts, which may be of 18th

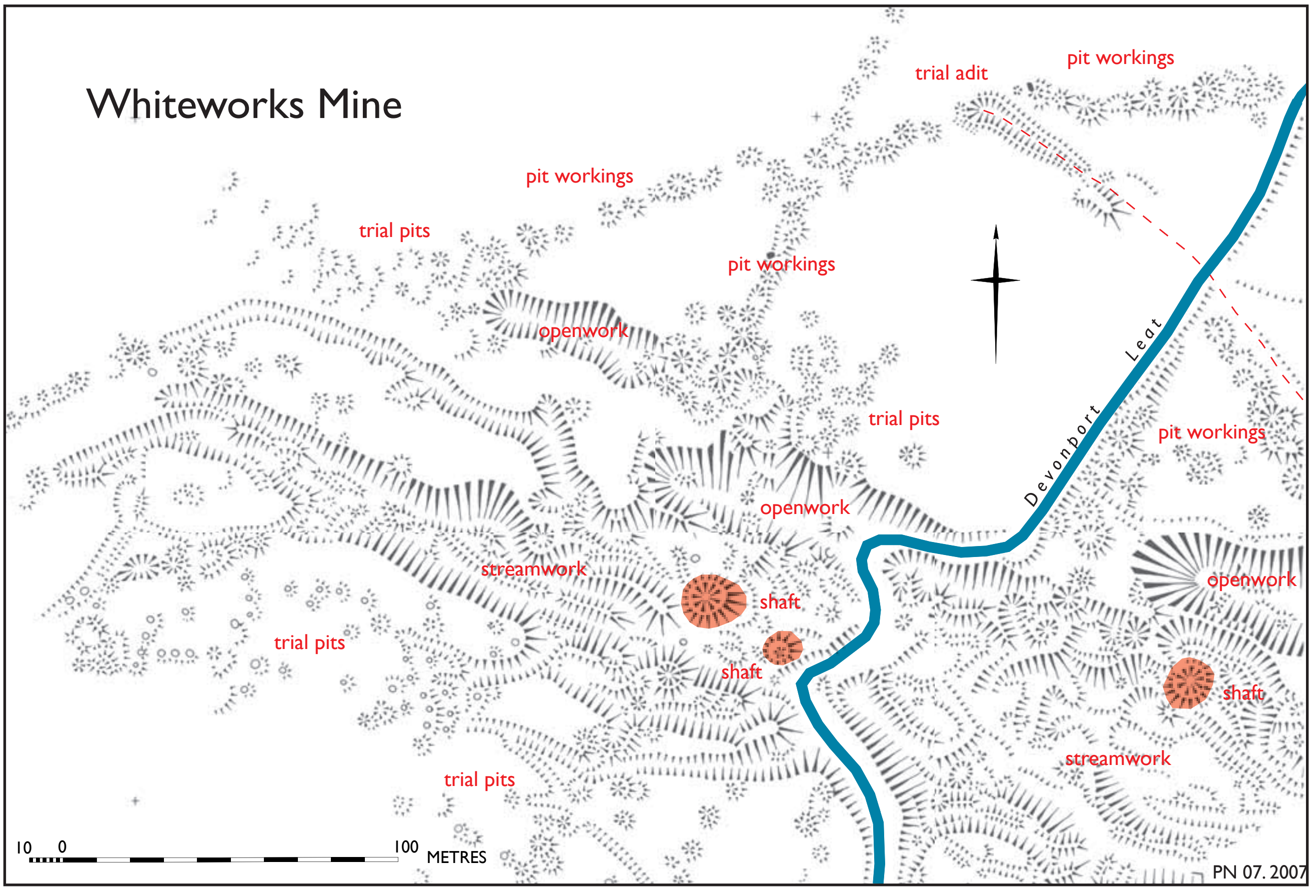


Fig 7.2 Part of an earthwork survey of Whiteworks Mine, surveyed at 1:1000 scale. This complicated area of tinworks is dominated by the streamworks though two deep openworks may also be identified as 'early'. An alignment of shallow pit workings runs WSW to ENE at the top of the drawing transected by a SSW to NNE cross course. The former was later explored by driving a trial adit along the course of the lode. Of contrasting character are areas of much smaller trial pits which survive at various points around the mine. The three large shafts with spoil collars within the streamwork (shaded) are likely to be associated with the 18th-19th century operation. The Devonport Leat, which transects the site, was constructed in the 1790s.

century date or earlier, which in turn has been cut into by a series of documented 19th century shafts. A similar scenario occurs at Whiteworks (Fig 7.2), where clusters and alignments of small trials pre-date the openworks on the north side, which must have effaced many other pits as extraction progressed. In both cases the trial pits evidently predated the elements representing 18th and 19th century extraction.

Prospecting pits at copper and silver-lead mines occur rarely, for the reasons explained above, and where they do, there can be no certainty that the prospectors were not searching for tin. At South Plain Wood, an unsuccessful copper mine recorded in 1849 and lying within the Metamorphic Aureole (*MJ* 05.05.1849), pits are present uphill from the 19th century mineshafts. Although unrecorded, these are very likely to be much earlier than the mine, judging by their silted and eroded appearance, but currently there is no means of knowing which metal the prospectors were searching for.

More common at copper mines are short undeveloped tunnels or 'adits' (see below), which are evidence of trials, as described by Pryce above. Several examples have been recorded along the River Dart near

Fig 7.3 Aerial photograph of Newleycombe valley. Shows the areas of tin streamworks following the base of the valley, alignments of prospecting pits, and larger pit workings. Just above centre is a small L-shape openwork which has been penetrated by later shafts. (NMR 24899/031)

Buckfastleigh, where a series of small companies searched for copper in the 1850s, including King of the Dart, Wheal Blackpool and at least one undocumented example (Fig 7.5). Such adits are usually blocked, although two of the above remain open and accessible. The clue as to their trial or prospecting status comes from the limited size of the spoil heaps outside the adit portals and the lack of corresponding shafts and surface infrastructure. Where the adits may still be entered they prove to be very short, coming to a dead end after only a few meters. Three examples penetrate a vertical slope at Holne Chase along the River Dart, all of which are of this type as are the three cited above. The Walkham valley below Bedford Bridge is also endowed with these adits, associated probably with Walkham United Mines, which were worked allegedly for lead, copper and a small amount of tin during the second half of the 19th century (BI, Buckland Monachorum) and probably earlier. Two adits at river level were clearly associated with the extractive activities of the mine, judging by their proximity to dressing floors and the substantive spoil heaps. Further up the hill to the south however, at least three blocked adits of limited depth were certainly trials. Their interior profiles are small, providing restricted access, and they each have a very limited spoil heap with no surface evidence of associated shafts. They are marked as part of an 'old workings' on an undated, probable 19th-century map of the mine (CRO ME 2463).

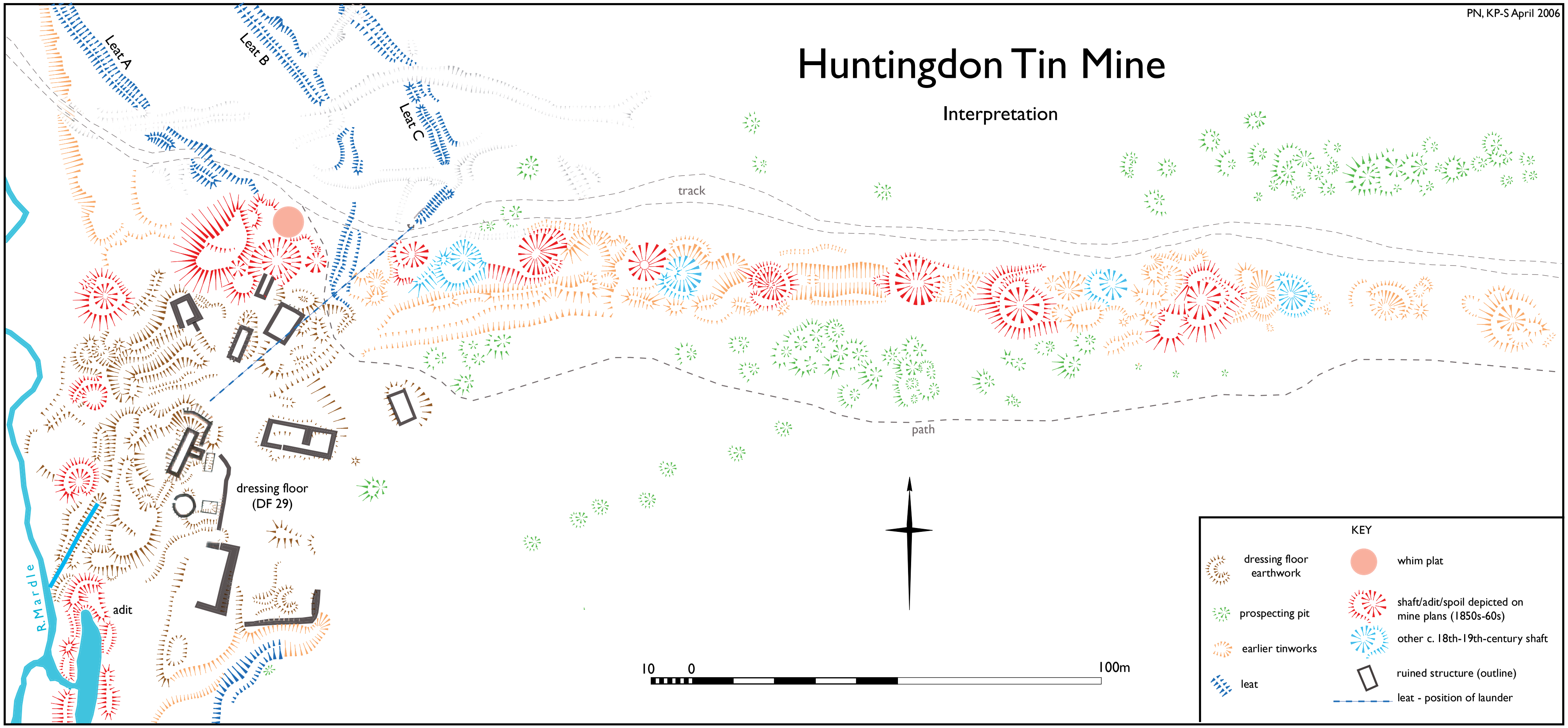


Fig 7.4 Interpretive plan based on an earthwork survey of Huntingdon tin mine, where colour denotes phasing of various features. The (undated) prospecting pits represent the earliest phase followed by the (also undated) 'early' shallow lode workings into which the later shafts, including those documented in the 1850's and 60's are an intrusion. Other shafts may be slightly earlier, possibly 18th century when the mine is first documented. Of the three silted leat channels, only Leat C appears contemporary with any of the lode workings, Leats A and B have been effaced by the mining activity and are therefore earlier.

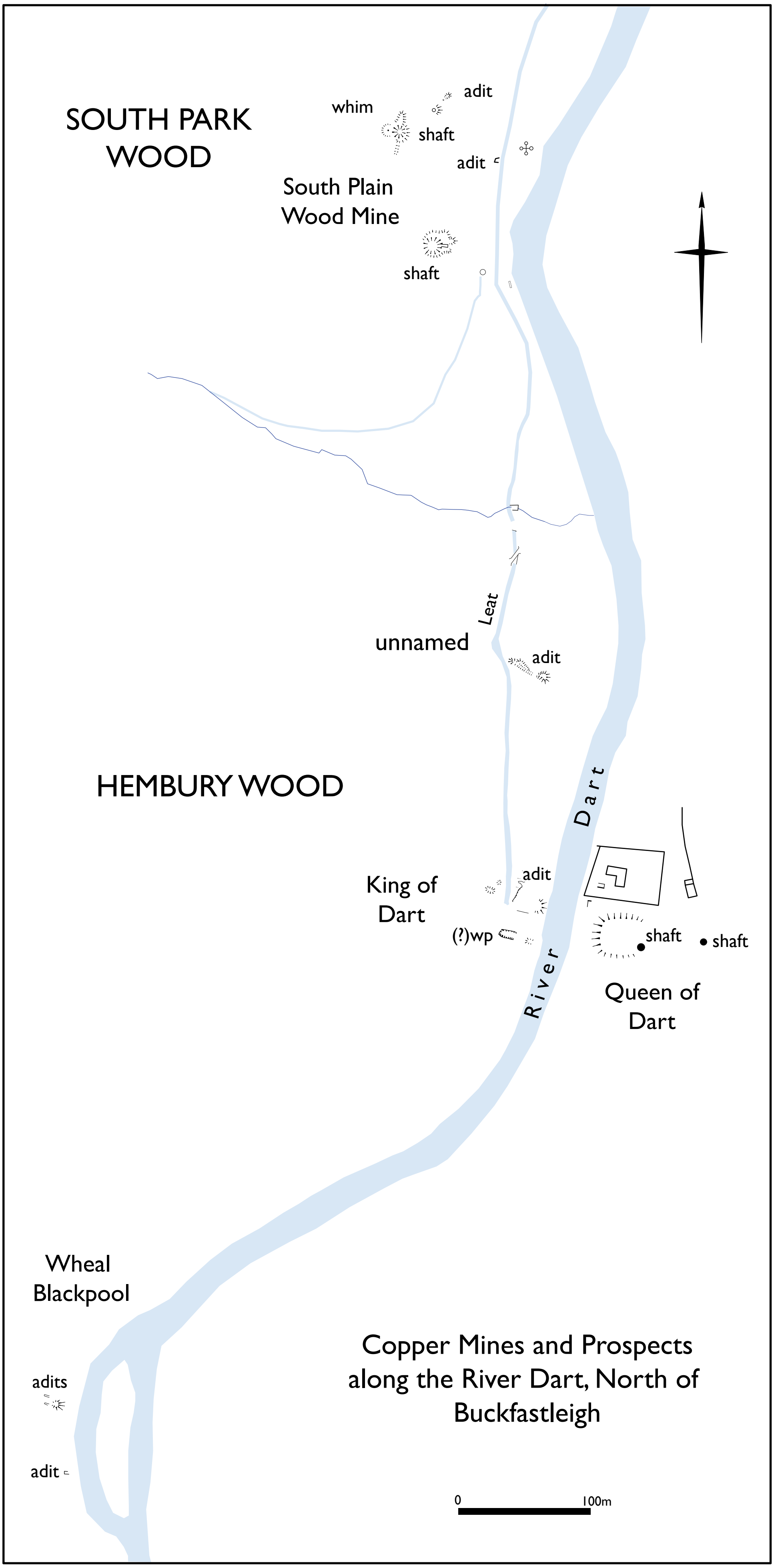


Fig 7.5 Copper Mines and prospects along the River Dart, north of Buckfastleigh showing the limited field evidence associated with these small prospects.

Evidence of trial adits has also been noted on the granite zone of the high moors, where the search was only for tin. In the valley known as Boveycombe Head, many exploratory adits were driven into the hillside to prove tin lodes that had previously been worked at surface, including Bush Down Mine, where two trial adits were driven east under an old openwork: again the limited spoil heaps provide evidence of how deep they penetrated. Further down the valley at New Vitifer (Fig 7.6), at least five blocked trials are present.

7.1.5 Lodeworkings before 1700

Openworks

Openworks are the remains of a method of exploiting a tin lode by digging open trenches onto the upper portion or 'back' of the lode. The working method, as used in Cornwall, was described by Pryce, who mentions that the trench or 'fosse' was termed a 'Coffin' and was created by digging a series of

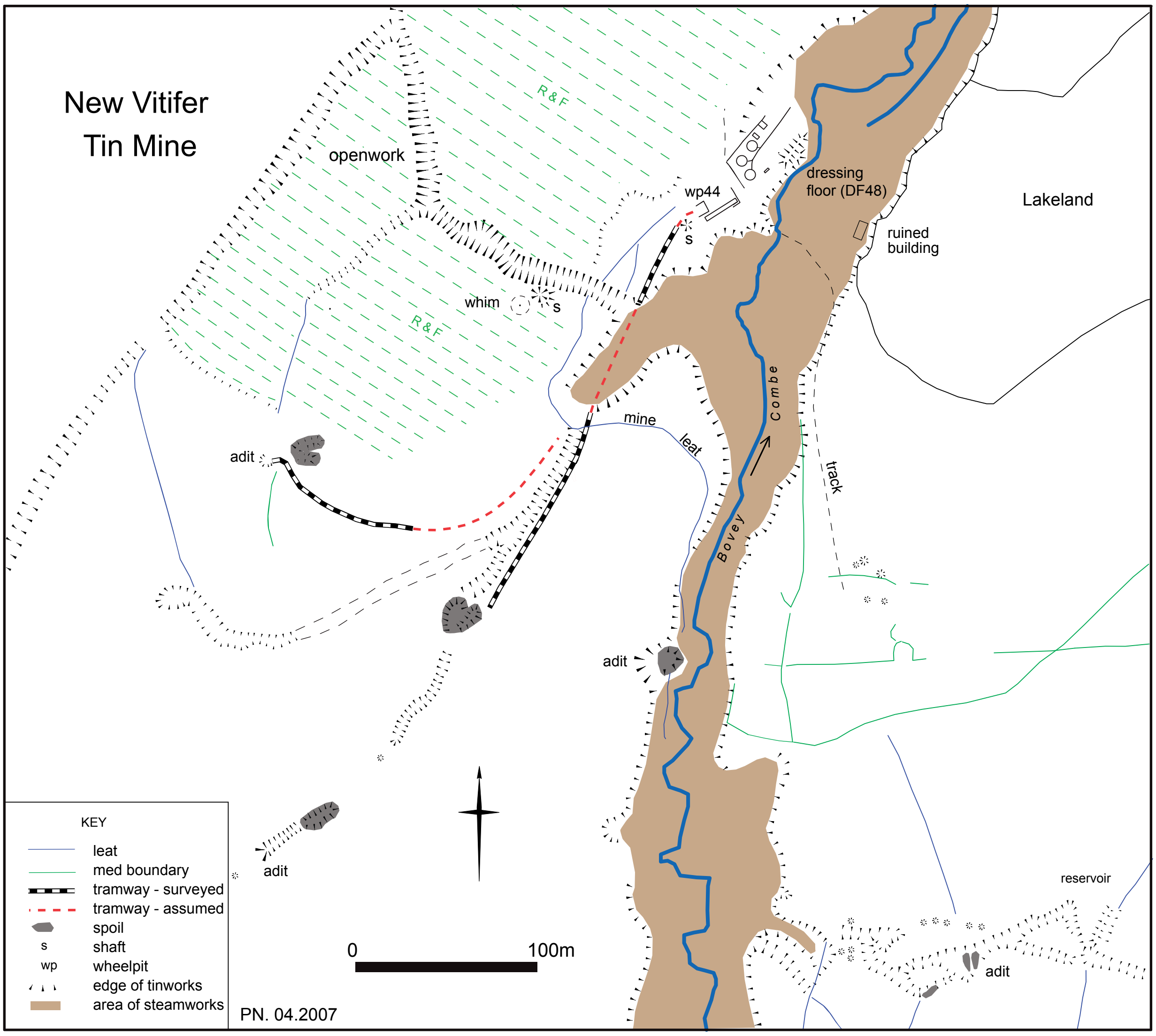


Fig 7.6 The Bovey Combe Valley and New Vitifer tin mine. Showing the engine shaft with horse whim plat, which was sunk adjacent to an 'old mens' working in the 1870s; a number of undeveloped adits with small finger spoil heaps; tramways; a dressing floor. Prior to the 19th-century, exploitation of the valley underwent episodes of tin streamworking, openworking and there is also evidence of medieval cultivation.

Fig 7.7 Aerial photograph of Ringleshuttes tin mines showing the linear earthworks and streamworks later worked to greater depth using shafts. (NMR 24012/027)

conjoined rectangular pits, which were stepped in height along the course of the lode, a technique know as ‘shammeling’, so that material could be shovelled upwards from one shammel to another. Work continued until the lode was found to be: ‘too deep for hand work, too small in size, too poor in quality, or too far inclined from its underlie for their perpendicular workings’. Pryce considers that this method was in use some 300 years prior to his own time, i.e. in the 15th century (Pryce 1778, 141-2), and Borlase describes the opencast or ‘Coffen’ method as ancient in 1748:

> *being a method too operose and expensive, it was not long,.....before the tinners learned to make passages into the bowels of the earth*
>
> (Borlase 1758, 168)

Unfortunately no early account of working Devon’s openworks, or ‘beamworks’ as they were known

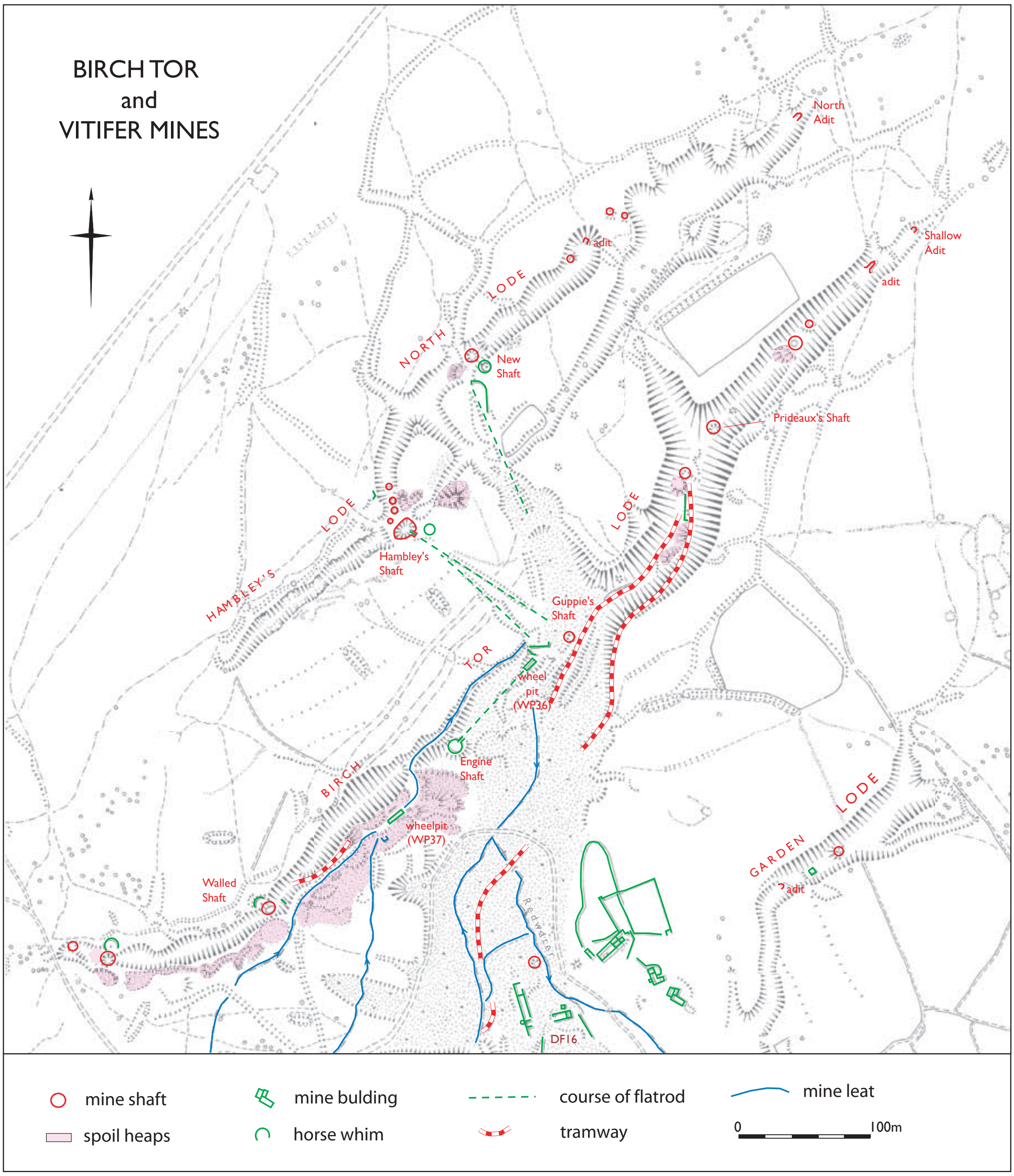


Fig 7.8 1:2500-scale earthwork survey of part of Birch Tor and Vitifer tin mines. Nineteenth-century mining features are highlighted in colour, overlying the earlier streamworks (stippled), openworks and associated leats prospecting pits and other earlier earthworks in grey.

in this county (Greeves 1981, 140), survives although about 150 beamworks have been identified from documentation (*Ibid,* 140) and Gerrard reports that there are 300 examples (Gerrard 2000, 87), though this is unverified. One thing that is certain is that this technique had fallen into disuse long before the commencement of the study period in *c.*1700. The most impressive examples are to be seen at Hexworthy, Ringleshuttes (Fig 7.7) Birch Tor (Fig 7.8) and Newleycombe Valley. They comprise massive cuttings with sloping sides of up to 12m deep, though they are now heavily silted. Some of the longest examples at Vitifer are 500m long by 50m wide and the interiors often have later shafts sunk into them, associated with known periods of later activity.

Two notable exceptions to the early dating of openworks have to be mentioned. These are Ausewell Wood Mine (Fig 7.1), and Holne Chase Mine. The former was a copper mine which was well established by 1724 though continued to be worked sporadically through the 18th and 19th centuries, finally closing in 1860 (Newman 2004, 2). Holne Chase less than 1km from Ausewell, was an undeveloped tin prospect, for which documentation is available from 1859. A second burst of activity in 1874-7 resulted in the sale of just over 4 tons of tin (Newman 2006). Both mines are within the Metamorphic Aureole and have been worked by open cuttings in the surface of the rock. Neither can be assigned a pre-1700 date however, as both have evidence of shot holes in the faces of the rock, caused by the use of explosives. The approximate 30mm diameter of the shot holes points to a post-1717 date for such workings (Earl 1978, 17). The use of explosives in this manner constitutes a different technique to that of the medieval openworks in a method akin to quarrying and in these cases can be explained because these sites represent extremely rare examples of ore outcropping at surface which were not worked in earlier times. Openworking using explosives was probably the most practical means of exploiting these outcrops.

Working tin lodes underground

The mining technique of digging shafts to provide access to metallic lodes has been in use since at least Roman times in Britain – at the Dolaucothi gold mines for example in south Wales (Burnham & Annels 1986, 27-9). In Devon the earliest recorded use of shafts was in the Bere Ferrers silver mines, commencing in the late 13th century where the technique was apparently used extensively (Claughton 2003, 141). Knowledge of shaft mining in hard rock and the skills to practise it must therefore have been available in Devon during that period but as yet there is no evidence that contemporary Dartmoor tinners were using it, or that copper was being exploited by such means.

However, by the late 16th and into the 17th centuries, underground mining was clearly considered to be the norm in Devon tin mines. The anonymous writer of 1671 (Anon 1671, 2105) described underground mining techniques, albeit at modest depths, which included shammelling, shafts, adits and raising water using kibbles and winders (see below). Prior to this, in 1599, the Devon historian John Hooker also alluded to mining when he described Devon tinners as spending their time ‘like a mole or earthworm underground mining in deep vaults’ (Hoskins 1954, 133). At about the same time Richard Carew described the mining of tin lodes by sinking shafts of up to 50 fathoms (91.5m) deep as common practice at Cornish tin mines (Carew 1602, 11).

Greeves concluded from his investigation of documentary sources, that the use of shafts on Dartmoor is likely to have earlier origins, stating that it is: ‘not unreasonable to place the start of shaft mining of tin deposits in Devon in the 15th century’ (Greeves 1981, 154). But as Greeves himself observed, the sites which provide the main sources of evidence cited, including Furzehill, Bottle Hill, Caroline Wheal

Prosper and Owlacombe, are all peripheral to the granite mass and: 'were not so remote from routes of communication or centres of population as the high moorland sites' (*Ibid*, 154).

This may have been one factor in the introduction of shafts but all three mines are also located within the Metamorphic Aureole, where the more workable shales or 'killas' would have been far more conducive to the digging of shafts using the developing technology available, rather than within the much harder granite.

Even if these occurrences are considered atypical of the 15th century, Hooker's testament, cited above, seems to confirm that underground mining for tin was commonplace by at least the end of the 16th century in Devon, and the fact that in 1630 Risdon (Risdon 1811, 8,) fails to mention streamworks, referring only to mines, suggests that even by then underground mining of tin was of greater importance. Nevertheless, streamworking must still have accounted for a significant proportion of the total output, judging by the number of documented early 17th-century streamworks (Greeves 1981, 302-50), although that total was by then in decline (Table 4.1).

Underground tinworking prior to 1700 may be considered to be of two types:

- shallow pit workings
- mines using shafts

but the developments of these slightly differing methods are not easily determined in temporal terms. The distinction between pit workings and mines with shafts is unlikely to be one that the tinners themselves considered. Gerrard noted that a lack of documentary references describing the operation that resulted in lodeback pits (his terminology), which are today considered to be a separate class of field evidence, might be because the tinners referred to all such pits as shafts (Gerrard 2000, 81). Pryce (1778) for example did not describe a method of working which would have resulted specifically in the field evidence for pit workings described below. However, although this is probably an erroneous distinction, it is retained here to define the difference between primary and secondary forms of underground working and the development of the techniques that are apparent in the field evidence.

There is one fundamental difference between shallow pit workings and mines. Pit workings concentrated on lode which outcropped at surface; to extract lode from a pit working, after removal of overburden, it was necessary only to work the hard rock of the lode itself. Whereas in a mine, where much deeper sections of lode were to be worked, huge effort was required to sink deep shafts and drive adits, through hard rock including granite, known as 'dead ground' before the lode was ever encountered. The investment of much development capital and effort, together with improved technology and skills described below, was essential for the latter. Deep mines therefore relied on the more developed and capitalized forms of mine management whereas logically this was less likely to be so for pit workings.

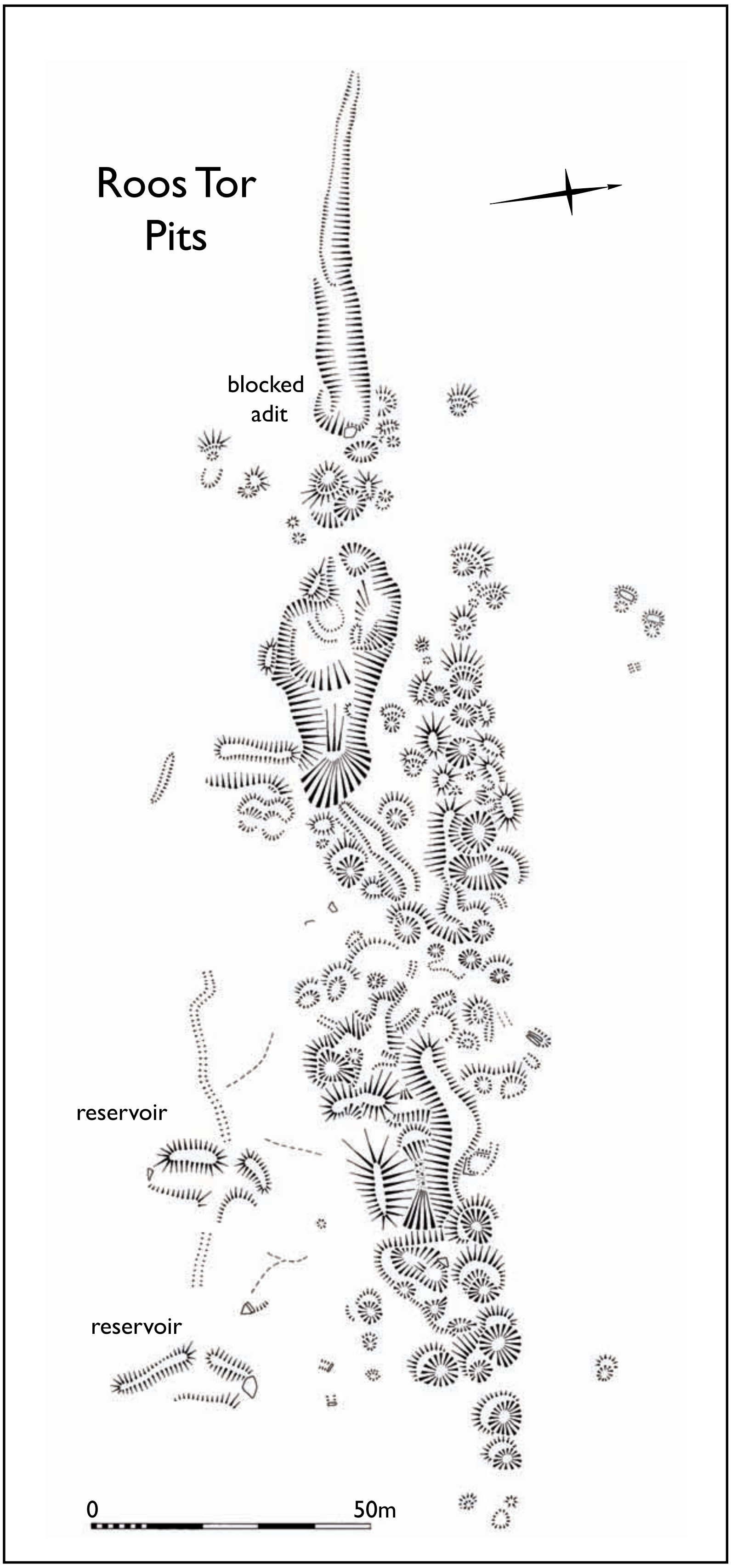


Fig 7.9 Earthwork survey of Roos Tor Pits; an undocumented lode tin work on the western slopes of Roos Tor. The shallow lode has been worked through a series of surface pits (pit working), some of which have merged. A blocked portal indicates the location of a drainage adit. There are no indications of this site having been worked by deeper shafts.

The actualities of this distinction and the chronological implications are far more complex. There is as yet no reason to suspect that pit workings were always from a distinctly earlier period than deeper mines, though it is very likely in most cases; nor do they necessarily represent undeveloped 'early' mining technology. They may simply represent a low-cost method of attacking shallow, unproven lodes, as opposed to the high-investment, more developed mining techniques necessary to prove and exploit lodes at greater depths. In the Peak District, where shallow lead rakes share many physical similarities with tin pit workings, it is believed that small, shallow workings operated by farmers and independent miners, continued to have a role in the 17th century and later, alongside the deeper mines being developed by wealthy industrialists (Barnatt & Penny 2004, 9). On Dartmoor, the working of shallow tin lodes using pits may also have continued in parallel with deeper mine methods for some time after the latter was introduced, perhaps well into the 18th century. Comparisons with the Peak lead mines are particularly relevant in view of the presence of free-mining traditions and prosperous medieval industries at both locations. Tin pit workings could therefore have continued as a method used by small independent adventures long after the introduction of deep mining techniques.

However, it is probably more likely that the same progressive behavior which led the tinners from alluvial works to lode works may have been applied at early mines, whereby the portion of the lode which could be extracted by digging simple shallow pits became exhausted and abandoned long before miners became committed to the additional labour and capital needed in underground working. The practicability of pit works using simple tools may have been made easier by the fact that the sections of the outcrops near the surface were part weathered and therefore more friable. No instances of chronological continuity from one method to the other have so far been noted from either fieldwork or documentary sources and if this occurred it will probably only be possible to prove through archaeological excavation. The most that can be said is that where surface evidence of deeper mines has been recorded at sites also worked using pit workings, earthwork survey has proved that the former are demonstrably later (Fig 7.9; 7.4).

The most informative text describing the underground working of tin prior to 1700 is the anonymous writer of 1671, who provided a detailed description of mining techniques in use at that time. Following the discovery of a lode (see above for the same writer's description of prospecting), a shaft was sunk using the same shammel or 'shamble' procedure described by Pryce as used in openworks:

> *We sink down about a fathom, and then leave a little long square place, termed a Shamble, and so continue sinking from cast to cast (i.e. as high as a man can conveniently throw up a shovel,) till we find either the Load to grow small, or degenerate into some sort of weed, which are diverse….*
>
> *Then we begin to drive either West or East, as the goodness of the Load, or conveniency of the Hill invite; which we term a Drift, 3 foot over, and 7 foot high; so as a man may stand upright and work;…..and then we begin to rip the Load itself.*
>
> (Anon 1671, 2102)

The writer goes on to describe the driving of adits for unwatering the mine, and the need to remove the water using ‘Winder and keebles, or leathern bags, pumps or buckets’, should the workings extend below adit level (Anon 1671, 2107).

This description suggests that many of the methods of mining for tin, which would also continue to be used during the 18th and 19th centuries for silver-lead and copper, were almost fully formed in the 1670s, but implicit in this text is the fact that the mines described were, of necessity, not very deep; the preference for shammeling over winding, although winders are mentioned, and the use of fairly undeveloped, inefficient unwatering devices all point to shallow working. It is also notable that in such a detailed description, there is no mention of either firesetting or powder blasting of rock. Without these aids, underground progress must have been very slow if working in an area of hard rock. Indeed a near contemporary account describes underground working with hand tools only, stating:

> *They get out the Mine with a Pick-ax, but when it is hard they use a Gad (a tool like a Smith's punch) which they drive in with one end of their Pick-ax made like a hammer*
>
> (Ray 1674, 121)

Pit workings or lodeback – field evidence

One problem with assigning pit workings with the term ‘early’ is that most are undocumented and none have been dated archaeologically. Relative dates are therefore largely an assumption based on the fact that they were earlier than any documented mines that worked the same lodes at a later date, typically leaving field evidence that would accord with the 17th century (or later) methods described. The miners themselves also had no way of knowing the age of the underground elements of previously worked mines if earlier activity was evident in the landscape and had occurred beyond living memory, they would refer to all such workings as ‘old men's’ workings or the work of the ‘ancients’ (Chapter 5).

The surface evidence comprises rough alignments of conical pits, each representing the upper section of a shaft which has been backfilled following abandonment. A collar of spoil, which, on sloping ground has a crescentic footprint, always surrounds the head of the shaft. Commonly the pits are roughly circular, though often they are amorphous. They are sometimes conjoined forming bigger pits and where several are joined they merge into irregular linear trenches with spoil lining the edges, such as at Huntingdon (Fig 7.4). The lines of pits usually follow approximately the strike of the lode trending E.N.E or E.S.E for caunter lodes. Although common on all parts of Dartmoor where lodes occur, the most concentrated area of these pit workings is in the Newleycombe valley on south-west Dartmoor, where they are interspersed with openworks, streamworks and later mines (Fig 7.3). One element missing from the anonymous (1671) writer's description is the spacing between the shafts and herein may lie one of the main differences between surface evidence of a shallow pit working and a fully formed mine. The pit works are often very close together, sometimes almost confluent, as at Roos Tor Pits (Fig 7.9) whereas true shafts are spaced at much greater intervals.

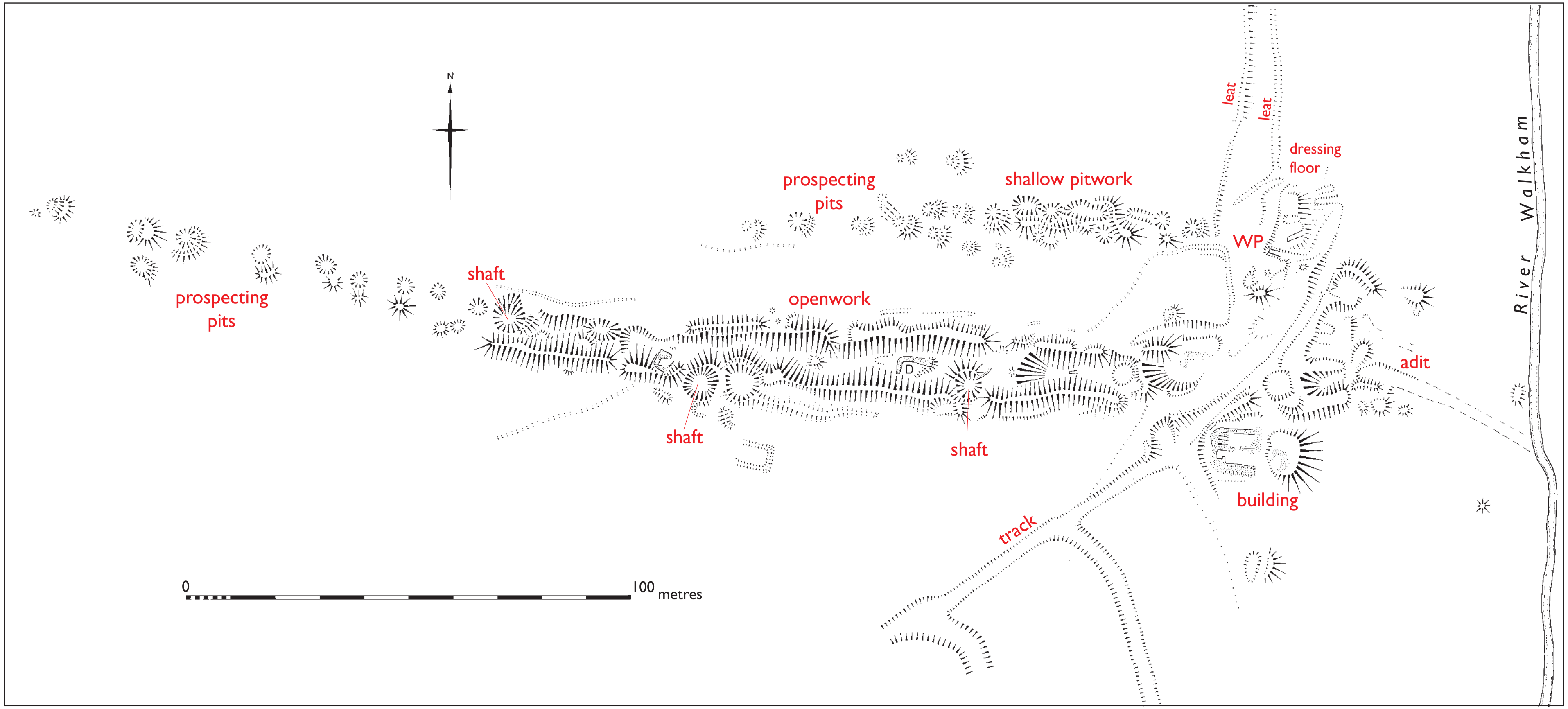


Fig 7.10 Earthwork plan of Wheal Prosper, showing the contrast in size and appearance of the later shafts and the earlier pit workings and openwork.

Exactly what lies beneath the ground at these sites is uncertain. Surface spoil heaps are not usually large, indicating the depth of the pits is, in most cases, limited to only a few metres. The spoil comprises soil or growan (decomposed granite) and rarely of rock, which suggests the pits were only sunk into subsoil and once the outcrop was reached, only the lode was removed and raised to grass, not the 'deads'. Adits have been identified at a few pit working sites including Roos Tor (Fig 7.9) and Whiteworks. It is probable that drifts extend laterally between the shallow shafts as described by the Anonymous writer of 1671. Occasionally a collapse occurs at these sites, such as that at Black Tor in 2007, which exposed part of the shaft but no gallery (DTRG 2008 *Newsletter* 34, 9). Such occurrences are rare and an archaeological excavation of a Dartmoor pit working would go a long way in answering some of these uncertainties regarding method, depth and technique at these sites.

Sufficient archaeological recording has not yet taken place at Dartmoor's pit workings to make many general comments. Although detailed surveys of a small number of sites exist, such as Wheal Prosper (Fig 7.10), Huntingdon (Fig 7.4) and Roos Tor (Fig 7.9), more are needed at less developed sites. Of those pit working sites which have been observed through fieldwork, but not recorded in detail, it can be stated with some certainty that where no associated later phases of deeper mines may be identified, they have no evidence of water-powered pumping; horse or water powered devices for hoisting are absent; as yet these sites have no proven association with dressing floors or other infrastructure of the study period – this places them chronologically before the advent of all the techniques associated with the 18th and 19th century industry discussed below. However, ground that was disturbed using pit working techniques, along with openworks, was a highly attractive prospect to adventurers setting up tin mines from the mid 18th century but especially following the 'revival' from the 1780's onwards for reasons discussed in Chapter 5.

7.2 TIN and COPPER Mines after 1700

It is clear from the 16th and 17th-century writings cited above that shaft workings of moderate depth, exploiting shallow parts of the lode, were in operation on Dartmoor long before 1700 at tin mines and were being further developed for copper mines, which were active by this time; according to Buckley it was the miners exploiting copper lodes in Cornwall who developed the techniques for deep underground working (Buckley 2006, 84). Thereafter the essential basis of underground mining altered little, although improving technology allowed for greater depth if needed. William Borlase claimed in 1758 when referring to copper, that: 'As to the mining part, copper-workes do not differ from those of tin materially' (Borlase 1758, 203).

Mines have distinctly different field remains from those of the earlier pit workings, reflecting the depth and the complex surface installations needed to operate them. In terms of surface archaeology, evidence for extraction using developed underground methods provides one of the key indicators of change at

Dartmoor mines. It demonstrates the technological innovation required to carry out the tasks that allowed the deeper penetration needed to access further sources of ore, as demands for the ore increased and the capital needed to meet the challenges of exploiting these sources became available. This is also the most informative category of archaeological remains available for an investigation that seeks to establish the extent and endurance of individual mines and, when analysed collectively, this data can provide the necessary insight into the economics and productive significance of mining districts such as Dartmoor. Evidence which informs of the methods of pumping water and drawing (hoisting) materials to surface provides details of the scale of underground activity, but also informative is the mass of the waste heaps at surface and the means of moving material around. Lack of these elements would strongly suggest an undeveloped mine regardless of what other infrastructure and ore processing installations (Chapter 8) may exist at surface and should alert doubt as to the validity of any optimistic documentary reports which suggest the opposite.

7.2.1 Shafts

Field evidence

Shafts are vertical or steeply inclined tunnels that cut through the country rock to provide underground access to the lode-bearing areas of the mine. Clearly the most important and archaeologically informative portion of the shaft is its underground section, but where capped or backfilled, the surface evidence is all that is available for examination. On the high moors of Dartmoor, where the public has free access and where safety is paramount, only a handful of shafts remain open, all relatively shallow, such as those at Brimpts and Whiteworks mines. More open shafts survive in the private wooded areas that surround the upland, though they often have served as receptacles for rubbish.

Where shafts have been capped or backfilled, it is usually only the very top section that is visible as either a straightforward opening or as a conical pit. Where associated spoil survives and has not been used to backfill the shaft, it may remain as a collar surrounding it or as a large flat-topped mound beside the shaft, or in some cases as finger-shaped dumps extending from the shafts, such as at Wheal Mary Emma (Fig 7.11). These variations would depend on the hoisting and other installations used to raise and transport the waste material (see below).

Shafts may be divided into four functional categories:

- Pumping - usually referred to as, or named, ‘engine’ shafts
- Hoisting - sometimes referred to as, or named, ‘whim’ shafts or ‘drawing’ shafts
- Ladder shafts or ‘ladderways’ or ‘footways’ - gave access for the miners to reach lower levels
- Air shafts - used simply for ventilation

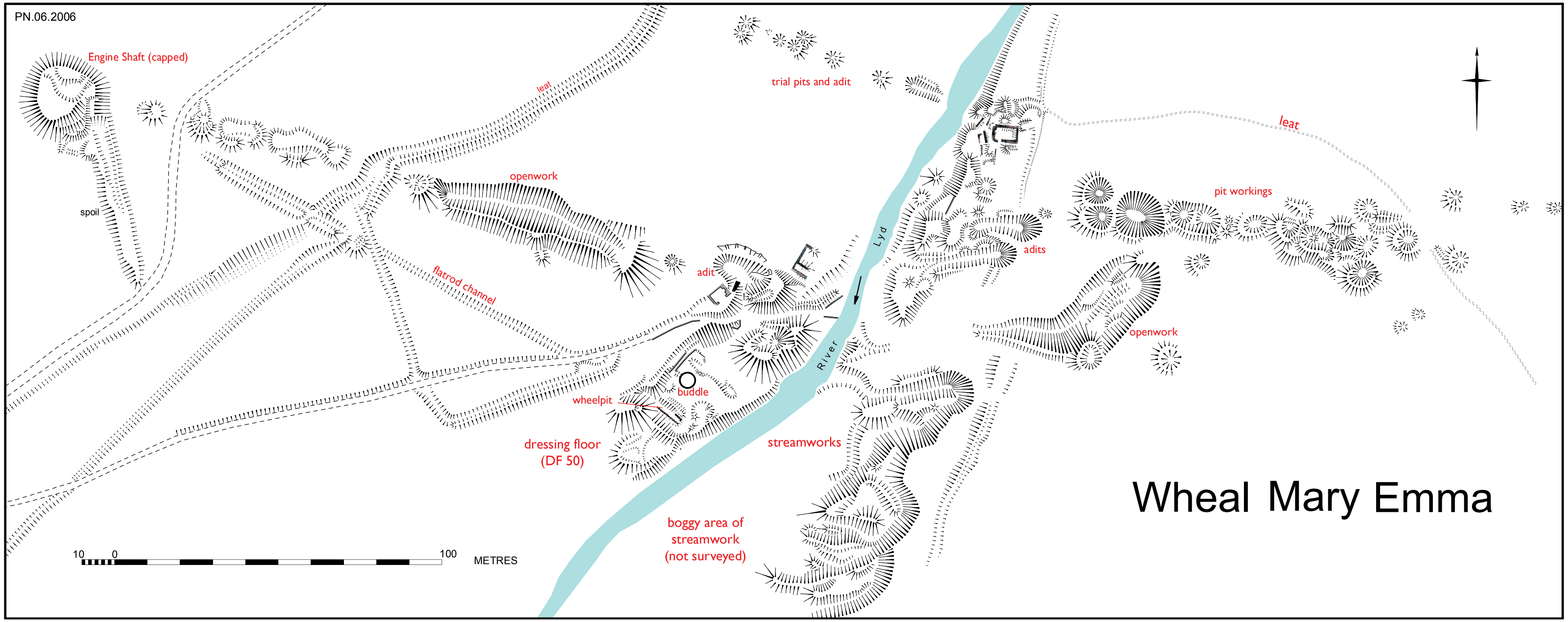


Fig 7.11 Earthwork plan of Wheal Mary Emma tin mine, showing early workings (pit workings and openworks) stradling the River Lyd, and 19th century workings in the form of shafts, adits, flatrod system, stamping mill and dressing floor.

These functions may sometimes be determined through documentation, but also by the variable field evidence associated, although often this may indicate that more than one function took place in the same shaft.

Pumping (engine) Shafts

When the depth of a lode exceeds that at which it is practical to drive a drainage adit, any attempt to exploit it below existing adits will result in those sections of the mine flooding, as the water has no means of escape (Fig 7.32). Unwatering the mine by mechanical means then becomes necessary to raise the water to the level of a drainage adit. The development of this technology was crucial in allowing miners to chase lodes to greater depths and is one of the factors often cited as central to the continuing success of metal mining in wet areas such as the uplands of the south-west peninsula, following the exhaustion of shallower lodes (Barton 1978, 18). Also however, pumping contributed massive extra cost to individual operations and pumping evidence has been noted at only 27 of the total of 104 mines where field evidence has been recorded, i.e. approximately one quarter of the sample.

Several techniques for raising water were available to the miners in the pre-18th century period, many of which were depicted by Agricola in 1556 (Hoover & Hoover 1956) in a European context and, writing of Cornwall in 1584, John Norden mentions 'pumps to exhaust the water out of the worke, and other engines for that purpose' (Norden 1584, 13).

The windlass (see below) could be used at surface or underground as a 'winder and keeble' as referred to by the anonymous writer of 1671, or powering a rag and chain pump. This latter device was introduced in the 15th century (Hollister-Short 1994, 83) and comprises a vertical pipe through which an endless loop of chain passes upwards powered by a horse, a windlass or waterwheel, and onto which leather plugs are fixed at intervals. The lower terminal of the pipe is submerged in the sump of the shaft and as the plugs rise up it they push water above them to be released out the top into troughs.

Kalmeter reported two separate but adjoining lead mines on Black Down on Dartmoor in 1724 where water was causing a problem (Brooke 2001, 10). At one of these, 'a water-wheel to draw water out of the mine with pumps' was in use, while at the other 'a rag and chain pump' was used 'to draw out the water', powered by an underground waterwheel. The fact that Kalmeter uses this precise wording, and goes on to describe how the rag and chain worked, suggest these were two different technologies and that the rag and chain clearly still had a role to play, even though pumps, probably of a piston type, were by then at work. Kalmeter also provides an illustration of the horse-driven rag and chain pump (Brooke 2001, 36) (Fig 7.12). The rag and chain was still in use in the 1750s in Cornwall when Angerstein witnessed it in operation, although he refers to it as 'old fashioned' and used only where the working was 'not too deep' (Berg 2001, 94). Pryce, in 1778, draws attention to the inefficiencies of the device and states that: 'they are now pretty generally laid aside on account of the great expense, and the destruction of the men' who worked them (Pryce 1778, 151).

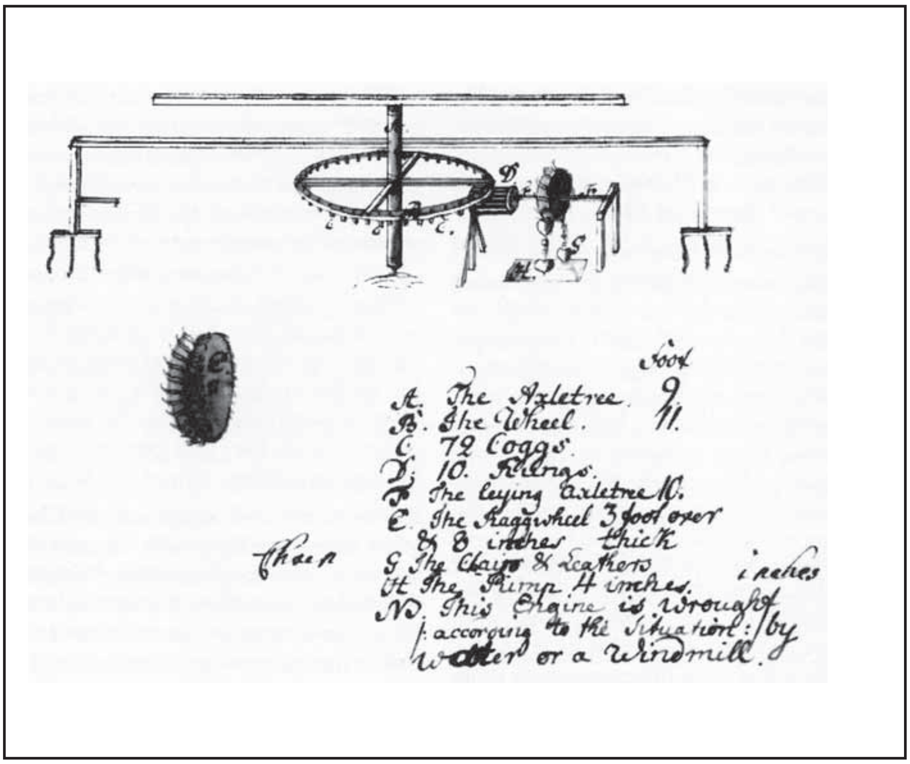


Fig 7.12 Sketch of a the surface components for a horse-powered rag and chain pump from Kalmeter's Journal 1724. (Brooke 2001)

But neither the rag and chain or the windlasses with kibbles are likely to have left any specific perceivable earthwork evidence at surface, and certainly none have been recorded in Devon. Rag and chain pumps were often installed below ground but if at surface the locations of these devices at the head of the shaft would almost always have collapsed downwards after abandonment or were destroyed when the shaft was backfilled. The horse whim, if used to power water-filled kibbles, is also difficult to prove from field evidence, but where a hoisting whim existed, water-filled kibbles could just as easily have been raised as those filled with ore.

Another method of raising water was witnessed by Hatchett at Wheal Friendship in 1796, where water from a 28fm shaft was hauled in buckets powered by a 26ft-diameter waterwheel (Raistrick 1967, 23). Unfortunately, detailed recording has not been possible at Wheal Friendship, and the identity of this shaft and the nature of the field evidence for this method is unknown.

Pumping using a piston to create suction, or a plunger using forced pressure, was a technology known at the time of Agricola in the mid-16th century (Hoover & Hoover 1956, 185) and according to Claughton (1996, 36), suction lift pumps were introduced to the Bere Ferrers silver mines in Devon in the 1470s. The technology was therefore quite clearly available in Devon long before the commencement of the study period in 1700, prior to which it is likely that tin mines had seldom reached the depths necessary for more powerful pumps, and copper mining, where the greater depth is needed, had not commenced.

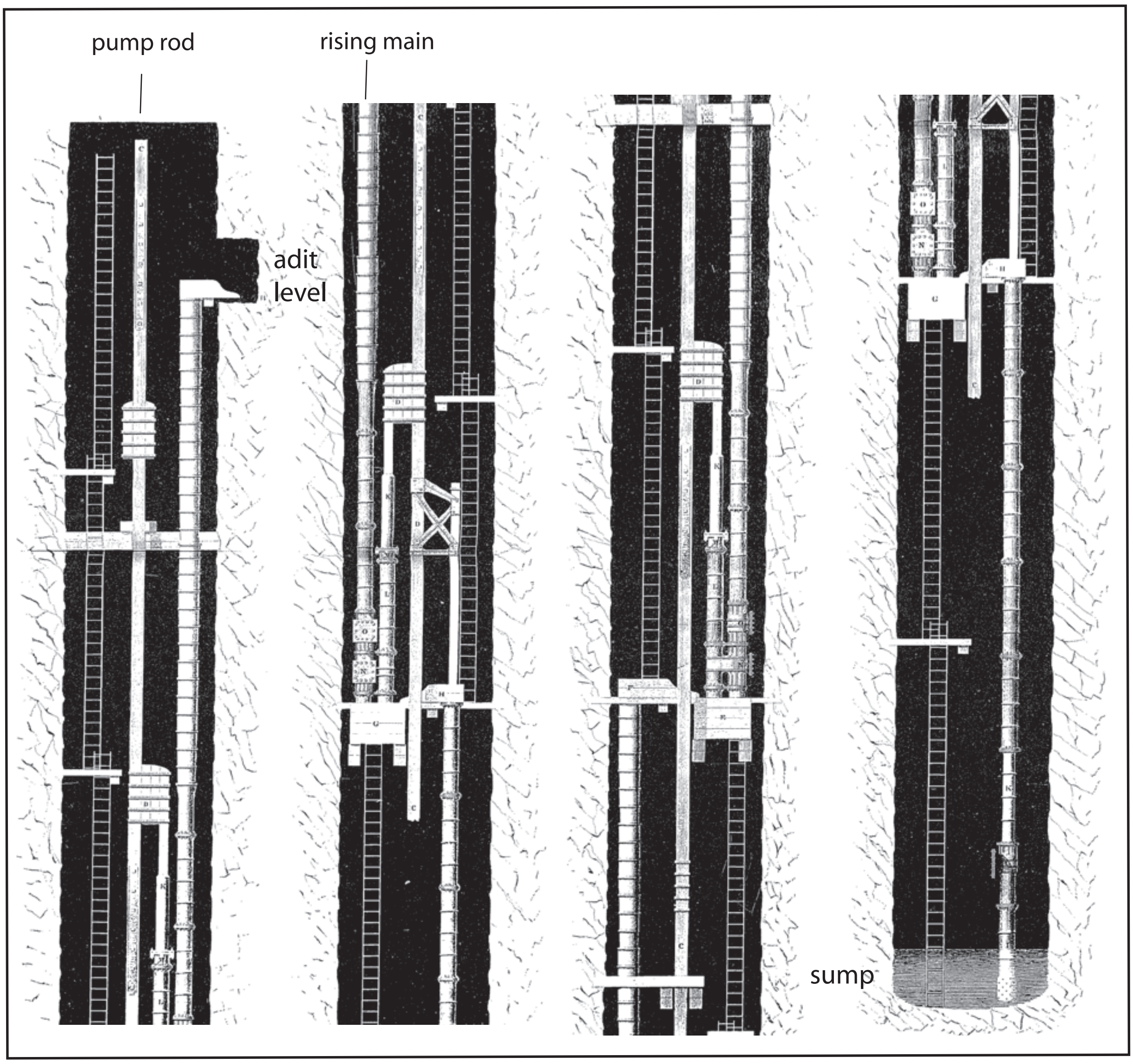


Fig 7.13 Illustration from John Taylor's Records of Mining (1829). Showing the underground components of Cornish 'pitwork' or pumping apparatus contained within a engine shaft. The pump rod connected at surface to either an angle bob, if power was drawn from a waterwheel, or a beam or bob direct from a steam engine.

According to the accounts of historians of Cornish mining such as Barton (1978, 18), it was the advent of copper mining in the Westcountry that brought with it the need to develop and invest in the technology to pump water from greater depths, resulting in the advancement of theses devices. Given the late development of copper mining in Devon and the general shallowness of the mines that were developed before about 1800, this is an unlikely scenario for Dartmoor.

The most informative contemporary description with illustration of mine pumps comes from John Taylor in 1829, a time that, according to Taylor, 'a degree of perfection had been attained' (Taylor 1829, 125) (Fig 7.13); descriptions and depictions have also been provided by Barton (1965, 91). Pumps or 'pitwork' as they were more correctly known, comprised cylindrical iron pipes or 'rising mains' which ran vertically up a shaft – or at an angle, depending on the course of the shaft – through which water from the bottom or 'sump' was raised. In earlier mines the water was moved by the suction lift method only, but by the time of Taylor's article a forcing pump was used whereby a plunger in an adjacent connected pipe, known as the wind bore, forced the water upwards. In both methods the piston was powered by a reciprocating timber pump rod running vertically down the shaft. The precise below-ground technology at individual sites cannot be determined using the methodology of this thesis and further discussion of it here is unnecessary. However, it was the means of powering and transmitting the power to the pump rod that has provided surface evidence; this in turn has enabled an assessment of the extent to which pumping was undertaken within the study area, how it developed and the choice of power source.

Shafts within which pumping equipment was installed were commonly referred to as 'engine shafts', and were frequently named after individuals associated with either the mine itself, or with sinking the shaft, recorded through documentation and contemporary mining maps. At Eylesbarrow (Fig 7.14) three shafts have the appellation 'engine' attached as in 'Henry's Engine', 'Old Engine', 'New Engine', for all of which field evidence for pumping survives (Table 7.2). A fourth shaft, also equipped with pumping evidence, is simply named 'Pryce Deacon's' (Newman 1999, 144-5). For many shafts, where annotated in documents, the simple label of 'Engine Shaft' is the most common, as at for example Huntingdon (AMP R120F), or Great Wheal Eleanor (AMP R220C). Such information provides useful clues when noted as a precursor to field reconnaissance.

7.2.2 Water Engines (Table 7.1; 7.2)

The main field evidence for water-powered pumps is that associated with their source of power. On Dartmoor the prime mover was most frequently a waterwheel, described in contemporary accounts as 'water engines', which activated reciprocating horizontal rods known as flatrods (see below), between the waterwheel and the shaft. Although waterwheels used to power pumps are often described in documentation in the 18th century, such as that cited above at the Black Down mines in 1724, field evidence which can with certainty be dated to that period has proved elusive and it is not until much later in the century that more specific historical evidence becomes available, though archaeological evidence is still somewhat patchy. At Whiteworks tin mine on central Dartmoor, a 'water engine' was being erected in 1790 (Greeves 1980, 11), but despite detailed archaeological survey of this site, it has not been possible to identify evidence of this specific waterwheel with confidence. A similar situation exists at Vitifer, which according to Charles Hatchet had a 36ft pumping water wheel in 1796 (Raistrick 1967, 22). This could be one of the surviving wheelpits, such as WP No 39, which could have accommodated a wheel of this size, but there can be no certainty as at least two other pumping wheelpits survive at Vitifer (WP36 & 37). The mine was extensively reworked and the surface infrastructure modified in the 19th and early 20th centuries (Broughton 1967/8, 25-49; Greeves 1986, 21-44), so there is a possibility that the wheelpit was destroyed or the wheel moved as work progressed. Hatchett also mentions a 26ft overshot wheel at 'Huel Jewel' in 1796 (Raistrick 1967, 22); although a substantial leat embankment

TABLE 7.1 Large waterwheel pits

Name of Mine	A	B	NGR (SX)	C	D	E	F	G	H	Date	J	References	K	L
Arundell	5	1	7451 7149	C	✓	3	19.1	1.5	7	1871	I	Newman 2003	E	-
Atlas	1	2	7780 7643	P(?)	✓	1	-	-	-	pre-1880	O	AMP, OS 25-inch	P	✓
Belstone Consols	83	24	6329 9390	P	✓	1	19.2	2.4	4	c.1878	I	Hamilton Jenkin 1981	G	23, 28
Betsy, Wheal (Gibbett)		31	5031 8066	P		1	-	-	-	pre- 1886	D	disused on OS 1886	P	10
Birch Tor & Vitifer (1)	12	36	6816 8122	P	✓	2	11.2	3	3	1856/67	O	Broughton 1968/9	E	6
Birch Tor & Vitifer (2)	12	37	6806 8110	P/H	✓	2	13	2.2	2.6	1856/67	O	Broughton 1968/9	G	6
Birch Tor & Vitifer (3)	12	38	6788 8082	H	✓	2	8.3	2.3	1.2	1856/67	O	Broughton 1968/9	G	6
Birch Tor & Vitifer (4)	12	39	6815 8090	P	✓	2	14.5	1.8	1	1857/67	O	Broughton 1968/9	G	6
Birch Tor, East (1)	46	34	6933 8090	H	✓	2	7.5	1.8	-	1852	O	Broughton 1968/9	F	✓
Birch Tor, East (2)	46	35	6934 8103	P	✓	2	-	-	-	1852	O	Broughton 1968/9	P	✓
Brimpts	15	45	6691 7386	P	✓	1	-	-	-	1798	I	Bird & Hirst 1996	E	22
Brookwood (1)	16	7	7177 6761	U	✓	3	10.5	2.2	-	Not Rec	-	-	F	✓
Brookwood (2)	16	9	7228 6756	P	✓	3	14	7.3	-	1840s	E	Newman 2005	P	✓
Brookwood (3)	16	8	7176 6752	C/H	✓	3	9.7	2.2	5.7	1875-1886	I	CRO HB/81; OS 1886	G	3, 27
Brookwood (4)	16	6	7179 6755	S	✓	3	10	2.26	4.3	1875-1886	I	CRO HB/81; OS 1886	G	3, 27
Brookwood, East	17	3	7203 8825	P	✓	1	13.2	1.5	3.3	pre-1869	O	EFP 24.2.1869	G	-
Caroline, Wheal	18	16	6684 8083	P		2	-	-	-	pre-1879	D	Page 1892	D	6
Devon Copper	68	14	5697 9173	P	✓	3	9	1.8	-	1860s	O	Hamilton Jenkin 1981	F	✓
Devon Great Elizabeth	26	4	7096 7070	P		1	-	-	-	1857-61	D	CRO DD/STA/viii/741/45	D	✓
Devon United	106	48	5120 7861	U	✓	1	9	1.3	6.2	after 1906	I	OS 1906 (absent)	E	24
Devon United	106	50	5117 7855	P	✓	1	8.7	2.1	1.6	1884-1905	I	OS 1884, 1905; Richardson 1992	E	24
Eleanor, Great Wheal	25	27	7351 8341	P	✓	1	12.8	2	4.5	1874-1878	O	MJ 04.05.1884	G	-
Emma, Wheal (2)	16	11	7159 6735	U	✓	3	10	2.1	2.7	1859	I	Newman 2005	E	3
Emma, Wheal (3)	16	10	7160 6762	P	✓	3	18.3	2.2	7.8	c.1878	I	Newman 2005	E	3
Emma, Wheal(1)	16	12	7150 6748	P	✓	3	16.2	2.2	-	1859	I	Newman 2005	P	3
Eylesbarrow (1)	1	30	5951 6802	P	✓	3	13.8	5.7	-	1815-18	I	Newman 1999	F	26
Eylesbarrow (2)	1	29	5927 6921	P	✓	3	19.2	6	-	1847-49	I	Newman 1999	P	25
Fortune, Wheal	29	32	5496 7551	P	✓	3	8.8	1.7	-	1800-1840	E	Greeves 1976	P	9
Gem, Little	74	41	4948 7055	H/P	✓	1	7.3	1.1	1.5	1871	O	BI, Whitchurch	E	✓
Golden Dagger	34	40	6781 8021	H	✓	2	8.2	2	3	1886-1905	I	OS 1886; OS 1905	G	6
Haytor Consols	9	47	7601 7523	P	✓	1	-	-	-	1863	I	BI, Ilsington; AMP R54B	P	✓
Hexworthy	35	13	6563 7088	P	✓	3	10	2	-	c.1890	I	OS 1886; Greeves 1986	P	✓
Huntingdon	7	42	6658 6650	P	✓	3	13.3	1.76	2.6	1859	O	AMP 15314; BI, Dean Prior	G	27
Ivytor	84	21	6268 9349	P	✓	1	9	1.8	-	after 1840s	O	Hamilton Jenkin 1981	P	✓
Jewell, Wheal	85	26	5186 8134	P		1	-	-	-	pre-1796	O	Mentioned by Hatchett in 1796	D	3
Katherine, Wheal	41	33	6103 6849	P	✓	3	6.4	1.7	-	pre-1856	D	Cook et al 1974	G	✓
Lady Bertha (1)	71	19	4711 6890	C/S	✓	1	10.8	1.5	3.6	1857-68	I	BI, Buckland Monachorum	E	12
Lady Bertha (2)	71	18	4712 6888	H	✓	1	12.2	1.3	3.2	after 1886	I	OS 1886	E	12
Lady Bertha (3)	71	46	4718 6886	P		1	-	-	-	1880	O	BI, Buckland Mon	D	12
Plym Consols	52	15	5858 6989	P		2	15	-		1836	E	Dickinson 1975;DRO 924b/B2/1	P	✓
Prosper, Caroline Wheal	53	17	7012 6586	P	✓	3	9.1	2	5.5	1854-7	O	Hamilton Jenkin 1981; MJ 22.10.1859	G	✓
Ramsley	28	28	6501 9290	P	✓	1	14.7	2.2	-	1864	O	Greeves 1995;	P	17
Smiths Wood	62	43	7728 7484	P	✓	0	-	-	-	1860-64	I	AMP R34C; BI, Ilsington	F	✓
Surprise, Wheal	82	20	5113 7403	P		1	10	1.4	-	1852	I	BI, Whitchurch	P	✓
Unknown (Cuddlipton)		53		P						Not Rec	-	-		✓
Virtuous Lady (1)	81	22	4746 6981	P		1	15	1.4	-	Not Rec	-	-	D	12
Virtuous Lady (2)	81	23	4738 6984	P/H	✓	1	10.5	1.6	-	Not Rec	-	-	P	12
Vitifer, New	65	44	6788 8273	P/S	✓	3	20	1.5	-	1870	I	BI, Chagford	P	✓

A = Site No
B = Wheelpit No
C = Purpose of wheel (P = pumping; H = hoisting; C = crushing; S = stamping; U = unknown)
D = Masonry surviving
E = Level of survey
F = Length (dimensions are only included where it has been possible to measure accurately)
G = Width
H = Depth
J = Date status (I = installation date; O = operational date; D = disused by; E = estimated date)

survives at this site, the wheelpit (WP26) was demolished and backfilled since disuse, surviving today only as a negative earthwork.

Among the earliest pumping wheelpits for which field evidence can be identified with more certainty is Beardown Mine, which is described in 1801 as having: 'an Engine lately erected for drawing water' (*SYM* 09.02.1801). Evidence of a heavily ruined wheelpit of up to 5m long has been recorded at this site (DF32) .

A little later, the installation of an engine wheel is recorded in 1815 at Eylesbarrow tin mine (WDRO 874/50/2). There are two surviving pumping wheelpits at this mine and it has been argued elsewhere that the 13.8m by 5.7m wheelpit (WP30) contained the wheel installed in 1815 (Newman 1999, 120). A second waterwheel of 50ft (15.3m) diameter, which reused the iron axle of the first, was installed between 1847-9 in a separate wheelpit (WP29).

The majority of the pumping wheelpits recorded as field evidence, for which documentation survives for their installation, were built from the 1840s to the 1870s (Table 7.1). They are among the largest wheelpits in the Westcountry, many examples housing wheels of 50ft diameter (15.4m) and upwards; the largest at Belstone (WP24) and Wheal Emma (WP10) were about 60ft diameter (18.4m) and field evidence for many other large examples survives, providing evidence that a good number of Dartmoor's mines were sufficiently deep to require substantial pumping installations, or it was the intention of the adventurers that work would proceed to greater depth in the future.

7.2.3 Flat rods (Table 7.2)

Engine shafts were seldom located close enough to a reliable source of water for the waterwheel to be sited nearby. The shafts needed to be where the lodes were found, often high on the valley sides, whereas the water supplies, normally rivers and small streams, were at the bottoms of the valleys. The wheelpits were often, therefore, built some distance from the shaft that accommodated the pumps and a system of rods, known as 'flat rods', would be used to carry the reciprocal motion needed for the pumps across the surface between these two points. Flatrod technology was probably introduced in Europe by the 1570s (Hollister-Short 1994, 86) but the date of its introduction at Westcountry mines, as with most technology, cannot be stated with any certainty. Flatrods were certainly in use by 1755 when Angerstein described one at St Just (Berg 2001, 111). For Dartmoor, it is likely that both the Whiteworks and Vitifer water engines cited above were activating pumps via a flatrod by the 1790s, but no field evidence can be assigned to either with certainty and the Beardown example of 1801 is probably the earliest documented with surviving field evidence.

Flatrod systems were sometimes depicted on 19th-century mine plans and section drawings prepared by mine companies, often illustrating the waterwheel, the flatrod – supported on alignments of short pylons

TABLE 7.2 Flat rod systems

A	B	Mine name	Shaft Name if known	C	D	E	F	G	H	J
8	30	Bachelor's Hall	Engine	DF8					✓	118
11	12	Beardown		DF32				✓	✓	185
24	19	Belstone Consols		WP24						630
12	6	Birch Tor & Vitifer (1)	Hambley's; Engine	WP36	✓			✓	✓	135
12	14	Birch Tor & Vitifer (2)	Dunston's	WP39						35
24	3	Birch Tor, East	Etheridge's (and others)	WP 35	✓			✓	✓	927
15	25	Brimpts (1)		WP45						-
15	28	Brimpts (2)		DF54						385
15	29	Brimpts (3)		DF55						60
16	18	Brookwood	Engine	WP9						-
79	11	Caroline, Wheal		WP16						270
68	35	Devon Copper		WP14						46
106	36	Devon United		WP50	✓	✓				70
17	22	East Brookwood		WP3						275
25	27	Eleanor, Great Wheal	Engine	WP27				✓		277
16	7	Emma, Wheal (1)	Emma	WP9				✓	✓	840
16	15	Emma, Wheal (2)	Pixton's	WP10	✓					165
1	1	Eylesbarrow (1)	Old Engine; Henry's Engine	WP30	✓	✓				672
1	10	Eylesbarrow (2)	Pryce Deacon	WP30	✓	✓				777
1	8	Eylesbarrow (3)	Henry's Engine; Pryce Deacon	WP29	✓	✓				961
1	26	Eylesbarrow (4)		WP29		✓		✓		1192
29	38	Fortune, Wheal		WP32						25
105	37	Freindship, Wheal	Bennett's	WP51				✓		203
34	34	Golden Dagger	Machine	WP40						-
9	16	Haytor Consols	Quickbeam, Prosper, Western	WP47	✓			✓		-
35	20	Hexworthy (1)	Lowe's	DF7	✓				✓	550
35	21	Hexworthy (2)	Taylor's	WP13	✓				✓	560
7	17	Huntingdon	Engine	WP42	✓	✓	✓		✓	527
85	31	Jewel, Wheal		WP26						-
71	5	Lady Bertha	Moyle's Engine	WP19	✓					55
49	13	Mary Emma, Wheal	Tindall's Engine	DF50					✓	190
52	32	Plym Consols		WP15	✓	✓				10
53	2	Prosper, Caroline Wheal	William's	DF15		✓		✓	✓	675
62	9	Smiths Wood		WP43		✓	✓			270
38	23	South Plain Wood		-	✓					-
81	24	Virtuous Lady	Eastern Engine	WP22						60
65	33	Vitifer Consols, New		WP44						10
73	4	Walkham United		WP54					✓	46

A = site no.
B = flat rod no.
C = wheelpit no. (WP see Table 7.1; DF see Table 8.1)
D = shaft bob pit
E = balance bob pit
F = intermediate bob pit
G = angle bob
H = earthwork channel
J = approximate length of flat rod (from survey or from OS 1:2500

topped by flanged wheels or rollers to accommodate the movement – and any counterweights or balance bobs (Fig 7.15). All the hardware from these installations has long since been removed leaving only subtle clues as to their former existence.

Field evidence (Table 7.2)

Flatrods were made of iron, produced in lengths linked together. Fixed to one or both sides of the waterwheel axle was an offset crank to which one end of the rods was attached; as the crank rotated it provided the reciprocal motion to the rods which would run just above ground level. The iron pylons do not survive although at Hexworthy (FR35) an alignment of small earthwork mounds running between the wheelpit (WP 13) and Taylor's Shaft, provides a clue to their former position. Several of the flanged iron wheels were dispersed at this site after abandonment and could be observed on the ground until quite recently (Fig 7.16).

At Eylesbarrow mine (FR1,8,10; Fig 7.14; 7.17) a system of paired granite posts was used to support the flanged wheels; a method which has not been recorded elsewhere in Britain. The paired stones are between 0.3m and 1m high, set on average 0.4m apart with flat faces on the inside. The axles of the wheels sat in crude horizontal bearing slots cut into the top of the posts. Flatrods powered by both the 1815 and 1847 waterwheels (see above) used this system; the earlier wheel having a set of rods attached to both sides of the axle extending for 777m, and the later system on the second wheel ran for 1192m.

The most usual field evidence for flatrods occurs where rising ground necessitated the cutting of earthwork channels to convey the rods across the surface. Such channels are easily differentiated from water channels by their straightness, which may be quite striking on aerial photographs (Fig 7.18) and on surveyed earthwork plans. The channels usually also have a 'V' profile and the example at Hexworthy Mine (FR20) is particularly pronounced (Fig 7.19). The flatrod at Beardown Mine (FR12) ran through a shallow but straight channel leading up the hill, aligned with the long axis of the wheelpit. This is likely to be the earliest field evidence of a flatrod system on Dartmoor, installed in *c*.1801 but the majority of surviving flatrod channels had origins later in the 19th century. At Wheal Mary Emma (FR13; Fig 7.11) the distinct V gully of a flatrod probably installed in 1852 (*MJ* 12.02.1852) runs from the wheelpit, obliquely up a steep hillslope to the mine shaft 190m away. Also documented in the 1850s is Caroline Wheal Prosper (FR2), for which a flatrod is depicted on the undated (though the mine is known to have operated between 1850 and 1854 (Newman 2004b, 2-3)) abandoned mine plan (DRO AMP R79F). As to the field evidence, a straight, terraced cutting of 120m long is the only indication of a flat rod system which originally extended for 675m between the waterwheel (WP 17) and William's Shaft.

A clearer example is the flatrod channel that runs up the West Webburn valley at East Birch Tor Mine (FR3) (Fig 7.18) where intermittent, aligned channels extend along the former line of the flatrods. A

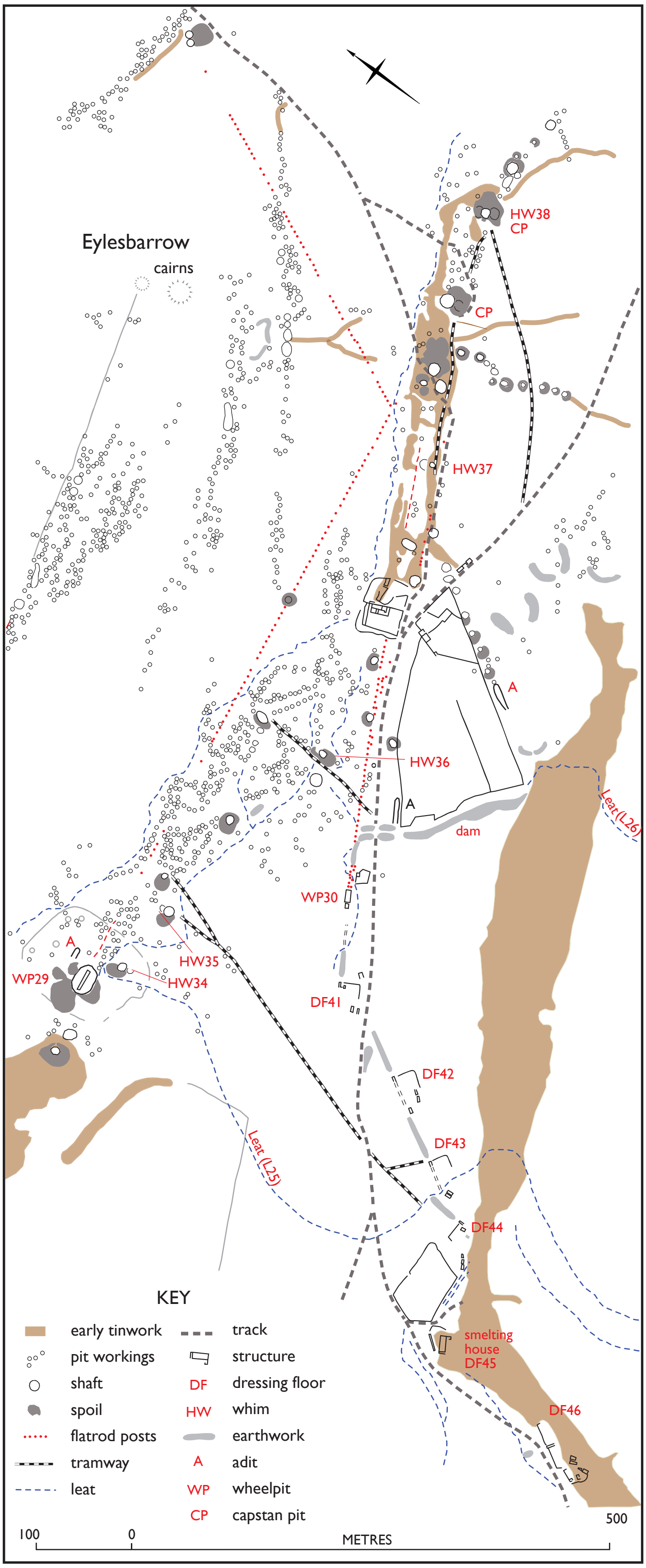


Fig 7.14 Simplified plan of Eylesbarrow Tin Mine based on a 1:2500 earthwork survey. Showing the locations of shafts, adits, surviving evidence of surface installations and water supplies.

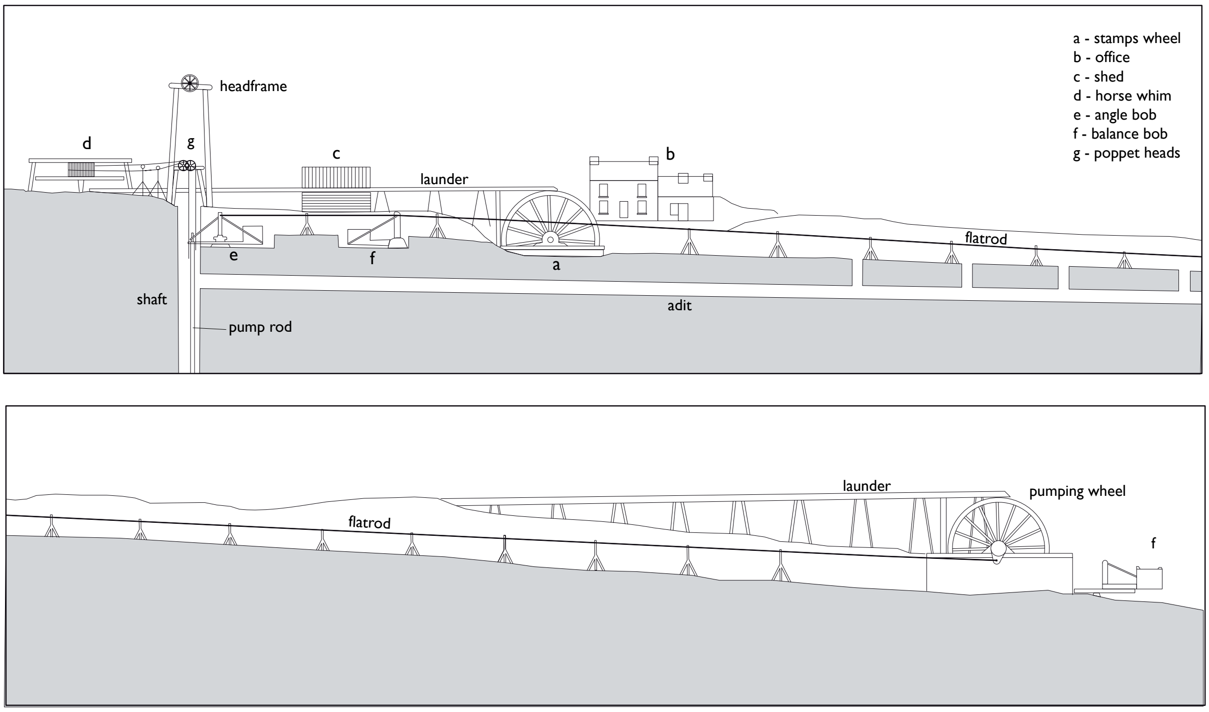


Fig 7.15 Sectional view of Huntingdon Mine, redrawn from a survey of 1866 (DRO AMP 15314). Shows surface installations operating at that time, including the 40ft diameter pumping waterwheel (527m from the shaft) and flatrod system, with three counterweights or 'bobs', the horse whim at the head of the shaft and the 40ft diameter stamping mill water wheel in its sunken wheelpit.

plan of this mine, published by Broughton, allegedly based on a contemporary mine plan drawn by John Penrose in 1852 (Broughton 1968/9, Fig. 4), shows the flatrod splitting into two, both lines deviating at an angle and leading to separate shafts. This was a common feature of flatrods whereby direction of the motion could be changed via a device known as an angle bob or turn bob, which was essentially a horizontal bell-crank, fixed to the ground with a vertical pivot. The angle bobs themselves have seldom left any evidence though at East Birch Tor an approximately rectangular stone-lined pit is in the precise position marked on Broughton's map and seems likely to have housed this device. At Wheal Friendship, an outlying wheelpit (WP51), now destroyed, powered a flatrod (FR37) leading to Bennett's shaft. A notable feature of this system is the stone structure to house the angle bob not far from the wheel, which has a rounded end wall imitating the travel arc of the bob. On five other examples, where no physical evidence could be identified, the former existence and approximate location of an angle bob has been determined through field survey by plotting the alignment of the flatrod channels, wheelpits and associated engine shafts, whereby any deviation in the line becomes obvious. Examples being Beardown (FR11), Birch Tor and Vitifer (FR12), Eylesbarrow (FR10), and Caroline Wheal Prosper (FR2).

At least three examples of pumping wheelpits are sited close to the engine shafts requiring only short sections of horizontal rods. These are Plym Consols (WP15), Wheal Jewell (WP26) and New Vitifer (WP 65; Fig 8.15). In the former case, the shaft was sunk low in the valley and an adjacent wheelpit needed only a short leat from the nearby stream, Newleycombe Lake. In the latter case the shaft was

Fig 7.16 A flanged support wheel from the flatrod system at Hexworthy Mine.

Fig 7.17 Paired granite flatrod supports at Eylsbarrow Mine. Flanged wheels with short stub axles, were supported in grooves in the upper surfaces of the stones.

only a few metres to the rear of the 60ft diameter waterwheel. At Wheal Jewel, although sited near the hilltop, the wheel was supplied by a very long leat, bringing water from much higher ground on the upland of north Dartmoor, giving some flexibility in the choice of location. Keeping the wheels at as

Fig 7.18 Aerial view of East Birch Tor mine showing the flatrod channel running along the valley floor. (NMR 21582/06)

great an altitude as possible, enabled reuse of the water on additional wheels for other processes lower down the valley. In the case of Virtuous Lady mine, this economy of water supplies also lead to one of the wheelpits (WP22) being sited at greater altitude than the shaft in which it activated pumps, which was down near river level.

Bob pits

Where a flatrod met the edge of the shaft its direction needed to change from horizontal to vertical as it headed down the shaft to the pumps. To achieve this, a vertically acting balance bob was used. In its simplest form this was a braced, right angle of iron or timber fixed to a fulcrum on which it could rock (Fig 7.15). Often however, a counterweight comprising a timber box filled with scrap iron or rocks, was incorporated into the bob, hence the term 'balance bob', which assisted the waterwheel when under

Fig 7.19 View looking along the flat-rod channel at Hexworthy, demonstrating its 'V' profile.

load, hauling the weight of the timber pump rods on the up stroke. This set up was frequently depicted on abandoned mine plans, Huntingdon being a very fine example (AMP R120F) where, unusually, two balance bobs were in use which operated together; one operating the pump rod in the shaft and the other simply acting as an additional counterweight. Alternatively, balance bobs were installed close by the waterwheel, where they served to keep the flatrods under tension.

Balance bobs were housed in a 'bob pit' – a sunken, stone-lined chamber set into the rim of the shaft, or very nearby on the exterior. The existence of a bob pit therefore offers definitive evidence that a shaft was, at some point in its existence, used to house pumps, even if no other evidence for flat rods exists. Conversely however, many known engine shafts have no evidence of a bob pit surviving, such as at Caroline Wheal Prosper and Beardown, the evidence perhaps in some cases having collapsed down the shaft or been demolished to be used as backfill, leaving no trace.

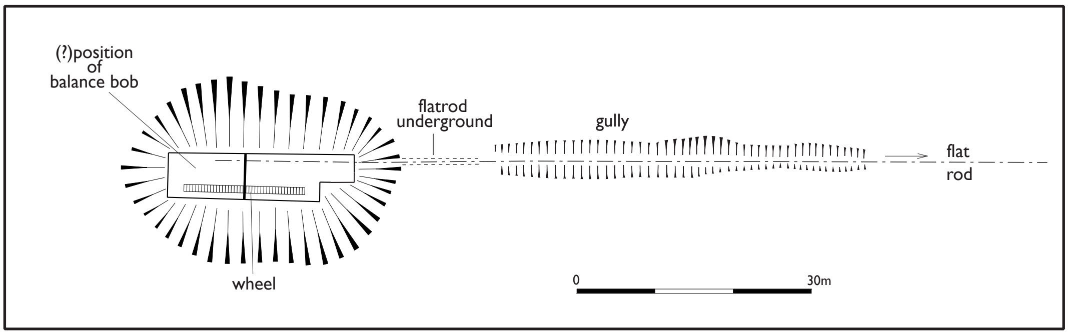


Fig 7.20 Plan of the engine wheelpit at Eylesbarrow Mine (WP 29). Showing the suggested layout for the flatrod installation.

Fig 7.21 A masonry lined bob pit at the head of Lowe's Shaft, Hexworthy Mine. The conical dip in the ground just beyond the pit is the head of the shaft.

Field evidence

Fourteen bob pits recorded at shaftheads are listed in Table 7.2, though it is likely that more remain to be noted. Illustrative examples include two at Eylesbarrow (FR8 & 26; Fig 7.14) both of which were, at different periods, served by two separate flatrods. The 6m wide sunken wheelpit (WP29), which housed the wheel to power one of these, is likely also to have contained a balance bob alongside the waterwheel (Fig 7.20). At Birch Tor and Vitifer, three bob pits have been identified and at East Birch Tor where two fine examples survive, that associated with Etheridge's Shaft (FR3) is perhaps one of the best examples within the study area. It measures 3.2m by 2.5m, sunk into the ground with a robust granite lining on three sides. Evidence of balance bobs is also often found in the vicinity of the wheelpits, where a counterweight was needed to keep the flatrods taut and assist the waterwheel when under load. At the Huntingdon pumping wheel (WP42), no pit was used to house the bob, instead two raised stone platforms beyond the end of the wheelpit kept it clear of the ground. At Brookwood (FR18), where the flat rod activated pumps over 840m distant in Emma Shaft, two bobs are illustrated on a plan of the site from the 1875 mine plan (AMP R66D). These were housed behind the wheel in a 6.2m square by 2.5m deep masonry-lined pits which survive.

7.2.4 Steam or fire engines (Table 7.3)

Steam engines designed for pumping water from mines were first used in coal mines in Staffordshire from 1712 and introduced in Cornwall as early as 1716 (Barton 1969, 16), when the Newcomen atmospheric engine was adopted at deep copper mines. The use of steam was so developed in the latter county by mid-century that writers such as Borlase (1758, 172) discussed steam engines in familiar terms, citing

TABLE 7.3 Engine Houses

A	B	Mine Name	NGE (SX)	C	D	E	Date	Reference
86	1	Wheal Betsy (1)	5102 8139	P	✓	✓		
-	2	Wheal Fanny	5203 8823	P		✓	1864	Nance & Nance 1996, 122
95	3	Anderton United		S				Financial World 1.12.1888
57	4	Ringleshuttes	6754 6986	P	✓	✓	1854	MJ 21.1.1854; 8.4.1854
5	5	Arundell	7450 7159	P	✓	✓	1852	Newman 2003; Nance & Nance 1996
16	6	Brookwood (1)	7171 6755	P	✓	✓		
61	8	Silverbrook	7890 7586	P	✓	✓		
60	9	Sigford Consols	7748 7507	P	✓			MJ
61	10	Silverbrook	7890 7586	H	✓	✓		Brook Index
9	11	Haytor Consols	7445 7607	P	✓		1854	MJ 21.1.1854
30	12	Yarner	7837 7837	P	✓	✓		
25	13	Eleanor, Great Wheal	7350 8342	S	✓	✓		AMP
21	14	Runnaford Combe	7013 6811	P	✓	✓	1849	Hamilton Jenkin 1981; Barton 1969, 112
18	15	New Brookwood	7235 6790	P	✓	✓		AMP
80	16	East Lady Bertha	4775 6900	H	✓	✓		
86	17	Wheal Betsy (2)	5101 8131	H				
16	18	Brookwood (2)	7173 6752	H		✓		
28	19	Ramsley	6510 9307	H	✓	✓		
90	20	North Wheal Robert	5128 7079	P			1856	Brook Index, Horrabridge
93	21	Sortridge Consols				✓		Barton 1969, 179
96	22	Wheal Exmouth	8373 8301			✓		
94	24	Devon Burra Burra	514- 741-	?P	✓			Hunt 1865, 33
67	25	Yeoland Consols	?		✓			
98	26	Owlacombe	7697 7295	P		✓	1857	Brook Index, Ashburton
109	28	Beam, West	7642 7344	P		✓	1861	Brook Index, Ashburton
109	29	Beam, West	767- 735-	S				
3	30	Atlas	778- 761-	P	✓		1859	Brook Index, Ilsington
105	31	Freindship, Wheal	?	P	✓			
32	32	Furzehill Wood	517- 692-	M	✓		1862	TG 31.01.1862

A = site no.
B = engine house no.
C = purpose
D = field evidence
E = documentary evidence

several Cornish examples in operation at that time. Later in the 18th century, Newcomen's concept was totally revised by James Watt who introduced the more efficient engine powered by steam pressure to the Westcountry mines and thereafter in Cornwall the beam or 'Cornish Engine' developed into the prime mover for pumping mines in a county where water to supply water engines was at a premium (Barton 1968, 156).

In Devon, steam engines were late to arrive. Lysons claimed that Wheal Tamar in the Tamar valley, which had been productive for thirty years, was the only copper mine in the county to have a steam engine in 1822 (Lysons 1822), but the first Dartmoor examples for which dates are known were installed as late as the 1850s, (Nance & Nance 1996, Fig 1), and the current number of steam pumping engines known, including documentary sources, is only 16 (Table 7.3) although steam engines for other purposes, including hoisting and stamping have been recorded.

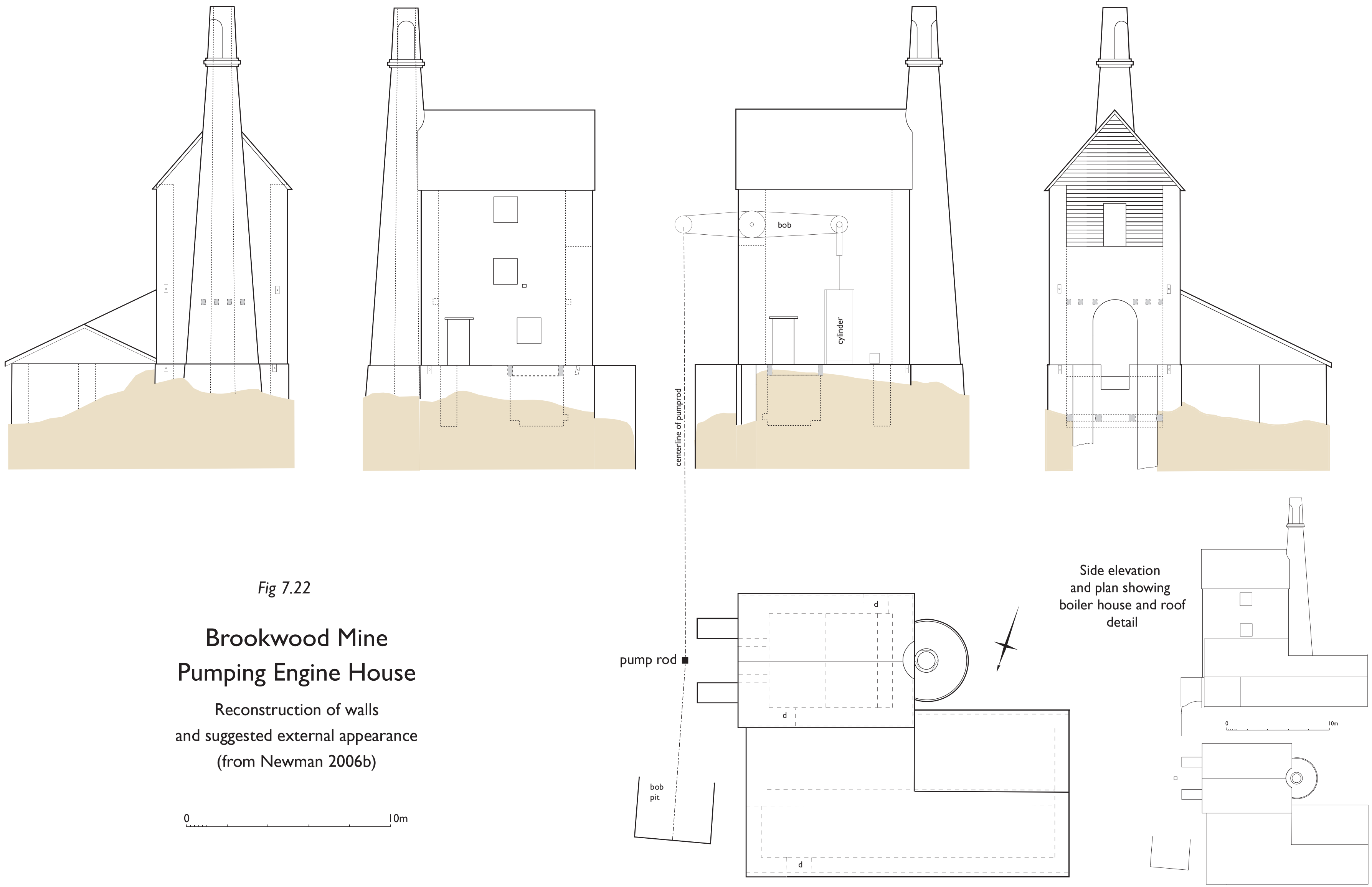


Fig 7.22

Brookwood Mine
Pumping Engine House

Reconstruction of walls
and suggested external appearance
(from Newman 2006b)

0 10m

The principle behind the beam pumping engine has been thoroughly discussed elsewhere in great detail (Barton 1965) and it is unnecessary to repeat such details here. Essentially, steam produced in a boiler, was piped into a vertical cylinder containing a piston. The piston provided reciprocal motion which, when connected to a horizontal beam with a central fulcrum supported above the cylinder, could be transmitted vertically down a shaft via a rod connected to the outside end of the beam, to power the pumps (Fig 7.22).

Field evidence

The field evidence for pumping engines consists primarily of the ruined buildings in which they were housed which was an integral part of the engine, not only containing the cylinder but also supporting the beam. Because, unlike waterwheels, steam engines did not rely on continuous high volume water supplies, they could be sited wherever required, as long as some water was available and in the case of pumping engines this was always at the head of the shaft. Motion could be taken from the beam or 'bob' of the engine directly down the shaft.

Unlike Cornwall, where intact or near intact engine houses remain as a defining characteristic of the mining landscape, on Dartmoor, of those that survive, very few do so as anything other than stumps (Fig 7.23) and several documented examples have not survived in any traceable form (see Table 7.3). The pumping engines for which either field evidence, documentary evidence or a combination of both survives were, in the majority of cases, at copper or silver-lead mines around the peripheries of Dartmoor; these tended to be deeper mines, such as Wheal Betsy (EH1). The latter reached over 140fms (256m) (MacAlister 1912, 76), while Brookwood (EH6) reached 120fms (219.5m) (*Idem* 77) and Arundell (EH5) 90fms (166m) (*Idem* 80). In all three cases substantial remains of the engine houses survive. One tin mine which was equipped with a pumping engine was Ringleshuttes (EH4), which at 400m OD was the highest and most remote engine house on the moor and comfortably within the granite zone. The engine house is so far undocumented but it is likely to have operated during a short recorded period of activity after 1852 (*EFP* 27.07.1854), when operating under the name of Holne Moor Mines; the shaft depth is unknown, though it is unlikely to be great, judging by the limited quantity of surface spoil. The choice of steam in this case was more likely to be due to the altitude resulting in a lack of collectable water to power sizeable water engines. The building survives only as a stump (Fig 7.23), surrounded with collapsed rubble including that of the chimney stack, but its location at the head of a shaft confirms that it was a pumping engine.

The late arrival and low number of engine houses can be explained firstly by the general lack of depth of Dartmoor's lodes mines, particularly within the granite zone. The undeveloped nature of Dartmoor's mines in the 18th century, when this technology was taking hold in Cornwall, is also a factor but foremost was the plentiful supply of water which allowed water power to dominate in this district and is discussed in chapter 9.

Fig 7.23 Ruined Engine houses at Druid (top) Ringleshuttes (centre) and Yarner(bottom).

7.2.5 Hoisting shafts

Essential to the operation of mines is a means of hauling and lowering materials up and down shafts. The material would include ore and waste (deads) being raised to the surface for processing or discarding, where not disposed of below ground, and the occasional need to move equipment within the shaft. The miners themselves were frequently photographed being hoisted up and down shafts as a speedy and less arduous, though certainly more dangerous, alternative to ladders (Earl 1968, 68; Hall 2000, 173 illus); a practice which was also known during Agricola's time in the 16th century judging by his engravings (Hoover & Hoover 1950, 213). Water was also raised using hauling devices where hydraulic pumps were not available, either in buckets (kibbles) or by means of a rag and chain pump.

The miners' choice of hoisting technology would depend on several factors, including the depth of the shaft, the nature and weight of the loads to be raised, sources of power available and the economics of the operation.

Gerrard has described a scenario whereby the more advanced forms of hoisting technology were adopted as a mine progressed deeper (Gerrard 2000, 101). However, this may not have been a seamless transition and it is possible that earlier efforts at a site could be curtailed because all the technology both pumping and hoisting fell short of that needed for the greater depths, and the further investment needed may not have been available or worthwhile where ores were not of good grade. Work may have resumed at a later date when the technology became available, or the economics of working low-grade ores became more favourable.

7.2.6 Windlass

Of the mechanical devices used for hoisting the windlass was the simplest and for that reason perhaps the earliest, the principle of the technology being known from Roman times. The windlass comprises a horizontal wooden barrel with axles protruding from both ends supported on upright timbers with a cranked handle at one or both ends. Rope was wound around the cylindrical barrel and the whole device mounted above a shaft or at the edge of an openwork, where loads could be raised or lowered by an operator turning the handle(s). The windlass is well recorded in contemporary literature and illustrations; Agricola was the first to explain its use at mines in 1556 providing a woodcut illustration of a hoisting windlass, but also showing it used to power rag and chain pumps (Hoover & Hoover 1956, 161). On William Borlase's cross-sectional drawing of Pool Mine, Cornwall, six out of eight shafts have a windlass mounted at the shaft head (Borlase 1758, Plate 18) and William Pryce depicts numerous windlasses in his cross-section drawings of mines, both at surface and below ground, the latter servicing the hauling needs in the winzes (Pryce 1778 (plate 2d; 4). A pithead windlass was recorded in a watercolour (Fig 7.24) of Vitifer Mine on Dartmoor by John Swete in 1796 (Gray 2000, 39). Despite its early origins, as an item of technology the windlass remained in use at mines into the 20th century and

Fig 7.24 Water colour by the Rev John Swete in 1797 showing a windlass above a shaft in the bottom of an openwork at Vitifer Tin Mine. (Gray 2000)

a photograph of 1906, taken at a mine in Derbyshire (Barnatt & Penny 2004, 10) shows one still very much in use. In 1671 the anonymous writer describing tin working techniques in Devon and Cornwall mentions 'winders' for raising deads and for raising water to the adit level; it seems likely that a windlass is what was being described.

Unfortunately the portable nature of the windlass means that examples rarely survive as surface evidence at mines, and certainly no specific field evidence of a windlass has yet come to light on Dartmoor. However, there are many situations, such as Whiteworks (Fig 7.2), where shafts and extractive pits, with a date range extending possibly from the 17th until the late 19th century, all have moderate collars of spoil but no visible remains of a hoisting device. In the absence of any other mechanised means of hauling, the presence of a windlass can be inferred with some justification, not only at Whiteworks but at many other examples like it.

7.2.7 The horse whim

The horse whim or 'gin' has been used on mines in many parts of the world as the principal hauling device in shallow to moderately deep shafts prior to the introduction of water, steam or electrically powered devices or, where such devices were not available or not considered necessary or desirable.

A perpendicular axle with a large horizontal cable drum known as the 'cage' mounted on the top, was rotated by means of yokes projecting from the axle, onto which one or more horses were harnessed; the whole structure was supported by a timber frame. The cable was wound horizontally onto the cage and extended to a head frame or 'poppet head' sited over the shaft which housed a wheel with flanged rims, across which the rope ran, changing its direction to run down the shaft.

There is disagreement among historians as to the date this device was introduced to Westcountry mines. Agricola illustrates the whim in use in mid-16th-century Europe (Hoover & Hoover 1950, 165), and

Earl (1968, 68) claims that the horse whim was imported into the Westcountry by Harz Miners, who themselves arrived in Britain in the 16th century. Others (Rowe 1953, 8; Barton 1961, 13) claim that the Bristol mining entrepreneur John Coster introduced the horse whim to the region in about 1720. Barton also asserted that the introduction of this device, and the working at greater depth which it allowed, was, together with more advanced pumping technology (above), a contributing factor in the opening up of Cornish copper mines in the early 18th century (Barton 1961, 13). Burt however, like Earl, is of the opinion that the horse whim may have been in use in the Westcountry much earlier (Burt 1991, 256) and indeed there is no reason why technology available elsewhere would be not be available in Devon and Cornwall.

Agricola's description and illustrations of a 'whim' from 1556, shows a device which differs little from those depicted by writers 200 to 300 years later. Angerstein for example recorded horse whims (Fig 7.25) during his travels in Cornwall in the early 1750s (Berg & Berg 2001, 105; 112), and on cross-section

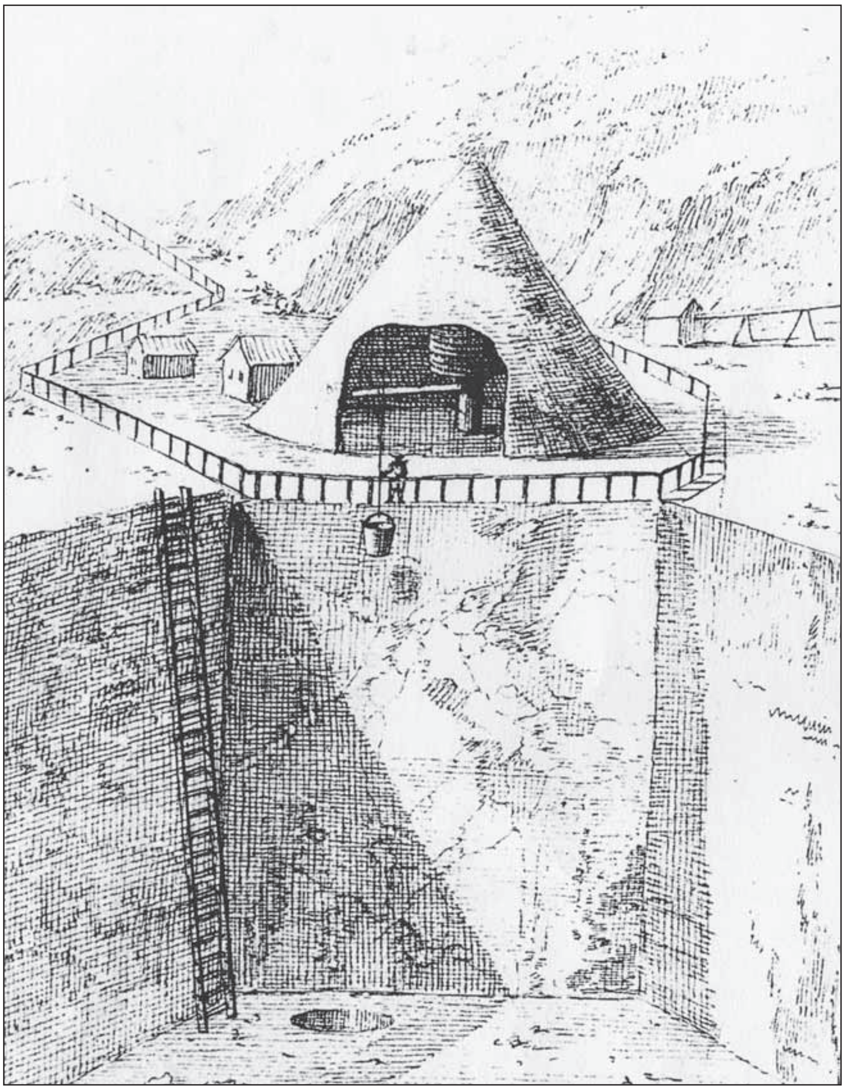


Fig 7.25 Sketch drawing from Angerstein's Illustrated Travel Diary, 1753-1755 (Berg & Berg 2001) showing a covered horse whim hoisting from a shaft in the base of an openwork.

drawings accompanying plans of Dartmoor Mines of the 19th century, such as Huntingdon (AMP R120F) (Fig 7.15) and Haytor Consols (AMP R54B), the essential principles and appearance of the device had changed little. Whims were frequently depicted with conical structures built over them as a protection from the weather. Such structures are visible on the illustrations of Agricola in 1556, Angerstein in 1758 (Berg & Berg 2001, Figs 106; 113), and Pryce in 1778 (Pryce 1778, Plate 4). Of great significance in some of Angerstein's scenes is the fact that Cornish mining landscapes of the mid-eighteenth century, as perceived by this particular observer, are characterised by multiple horse whims at spatial intervals across the landscape. His view entitled 'Tin Mines at St Austell' for example (Berg & Berg 2001, Fig. 92) depicts only open shafts and whims, of which seven are present.

This simple and reliable piece of technology survived until the end of the study period and beyond: a fine photograph of a whim still standing and in use at a Derbyshire lead mine is dated to the early twentieth century (Barnatt & Penny 2004, 15).

A comment particularly pertinent to the present discussion, made in 1873 regarding Cornish practice, was that:

> *in shallow mines ores are raised by a hand-windlass or tackle and in deeper mines by a horse whim or steam engine. As a rule the machinery for raising ore is greatly inferior to that used for pumping*
>
> (Collins 1873, 101).

By the late 19th century however De la Beche mentioned that: 'Horse whims are still very commonly used in small adventures or upon the shallow extended workings of the larger mines (1839, 573), and Davies referred to the whim as 'temporary' machinery used for 'prospecting' (Davies 1894, 64). Despite being superseded by more efficient hoisting devices it remained as a preferred technology in arid areas of Queensland, Australia where water-power was not an option and many examples survive there from the 20th century with timber components still in place (Pearson 1995, 7). There is no evidence however that the horse whim remained in use on Dartmoor beyond *c*.1900, after which time electric winches were available at the few mines which continued to operate, such as Hexworthy.

Field evidence (Table 7.4)

The only surviving archaeological evidence for whims on Dartmoor are the plats, or level circular earthwork platforms on which the device operated, and the centrally-placed mellior stones (flat-topped stones with vertical blind holes of approximately 60mm diameter) which accommodated the perpendicular axle. However, melliors are not always present or visible where plats survive. No trace of the timber components of either the whim or the shaft headgear survive.

Fig 7.26 A raised whim plat at Whiteworks (top) and a scarped example cut into the slope at Haytor Mines. The latter shows a misplaced mellior in the centre of the plat.

Forty-eight whim plats have been recorded in the course of this research and they were by far the most common hauling device in use on Dartmoor; others certainly remain to be recorded. The largest plat has a diameter of 12.5m and the smallest is 6.5m. Where a whim was used for hauling in a shaft the plats are sited adjacent to the head of the shaft, probably deliberately sited as close as possible for maximum efficiency. The levelled area is usually defined either as an artificially raised plateau, two examples of which survive at Whiteworks (HW15,16) where the local terrain is flattish (Fig 7.26) or, where more commonly on hillsides, the circular earthwork is cut into the slope, creating a crescentic scarp on the

TABLE 7.4 Horse Whims

A	B	Mine Name	NGR (SX)	Dia(m)	C	Associated shaft name
17	1	Brookwood, East	7183 6842	6.5		-
18	2	Brookwood, New	7236 6789	n/k		Engine
16	3	Brookwood	7194 6757	8		Martins
16	4	Wheal Emma	7160 6745	10	✓	Pixtons
16	5	Wheal Emma	7133 6738	12		Whim
35	6	Hexworthy	6511 7106	6.6		Taylors
37	7	Holne Chase	7233 7148	8.3	✓	-
20	8	Wheal Chance	5983 7021	10		-
18	9	Wheal Caroline	6709 8094	9.5		Whim
61	10	Silverbrook	7885 7576	6.5		-
38	11	South Plain Wood	6941 7326	10	✓	-
30	12	Yarner	7823 7831	7		-
59	13	Walkhampton Consols	5218 6965	10.4		-
40	14	Whiteworks	6134 7079	15		(?) Engine
40	15	Whiteworks	6117 7092	13.5	✓	-
40	16	Whiteworks	6115 7089	14	✓	-
76	17	Wheal Duchy	5844 7352	6		-
75	18	Wheal Lucky	5717 7484	8.5		-
82	19	Wheal Surprise	5100 7402	9.5		-
82	20	Wheal Surprise	5116 7398	11		(?)Engine
81	21	Virtuous Lady	4742 6988	8.5		Eastern Engine
85	22	Wheal Jewell	5256 8133	12.5		-
9	23	Haytor Consols	7556 7551	10.4		Western
9	24	Haytor Consols	7592 7553	8.5	✓	Prosper
-	25	Unknown (Gibbet Hill)	5019 8090	10.5		-
65	26	Vitifer, New	6777 8268	12.5	✓	-
32	27	Furzehill	5186 6924	n/k	✓	-
32	28	Furzehill	5176 6925	n/k	✓	-
12	29	Birch Tor & Vitifer	6796 8104	n/k		Walled (shaft 3)
12	30	Birch Tor & Vitifer	6785 8101	9		-
-	31	Unknown (Cramber)	5948 7090	n/k		-
-	32	Unknown (Gibbet Hill)	5034 8089	12		-
4	33	Brimpts	6511 7513	12		Engine
1	34	Eylesbarrow	5931 6817	9.4		Sutton
1	35	Eylesbarrow	5939 6818	8.8	✓	Henry's
1	36	Eylesbarrow	5964 6813	0		Whim
1	37	Eylesbarrow	5997 6824	12.5		Philp's
1	38	Eylesbarrow	6024 6837	12	✓	Pryce Deacon
1	39	Eylesbarrow	6014 6831	11.9	✓	Henry's Engine
7	40	Huntingdon	6679 6701	7.6	✓	Engine
8	41	Bachelor's Hall	5972 7347	n/k		Engine
12	42	Birch Tor & Vitifer	6809 8132	10.8		Hambley's
12	43	Birch Tor & Vitifer	6813 8144	10.2		New Shaft
12	44	Birch Tor & Vitifer	6780 8075	5.5		Lance's
2	45	Wheal Albert	5686 5956	9.7		-
9	46	Haytor Consols	7604 7583	12		Quickbeam
14	47	Borro Wood	7478 7160	10	✓	Borro Wood
113	48	Unknown (Cudlippton Down)	5303 7940	12		-

A = Site No; B = Horse Whim No; C = Mellior stone *in situ* upslope side. Where the slope is moderately steep, this scarp may be very pronounced as at South Plain Wood (HW11), Wheal Emma (HW5) and Silverbrook (HW10), New Vitifer (HW26), the latter having a scarp of over 1m high. Less pronounced scarps occur where the gradient is more gentle and may be very subtle, such as at Holne Chase (HW7) Henroost (HW6) and Wheal Caroline (HW9).

Several whim plats have low earth, or earth and stone, banks running around their circumference. The clearest examples recorded are on Gibbett Hill (HW25), where the bank surrounding the 10.5m diameter plat is 1m high, and Wheal Jewell (HW22) with a bank 1m high, the plat being 12.5m diameter. These banks may represent the base of the conical structures depicted by Angerstein and others, which surrounded the whim. For Eylesbarrow Mine, where the plat adjacent to Pryce Deacon's Shaft has a low stony bank surrounding it, a Cash Book entry of 1814 mentions 'Making a hedge round Eastern Whim (7yds 12ft)' and 'Western Whim (8yds)' (WDRO 874/50/2). The precise nature of this 'hedge' is not described but perhaps the bank supported a timber or lattice structure to protect the horse and driver from the worst excesses of the weather.

Although in a few cases a whim plat is dateable from documentation, a general statement about their date range is not straightforward. Where evidence of a whim has been recorded at the location of a documented mine, there can be no certainty that the whim does not date to a previously undocumented episode. However, none of those recorded have been found in association with 'earlier' pit workings, except where deeper shafts were sunk onto the lode at a later date (e.g. Huntingdon Fig 7.4). It therefore seems probable in these and other cases, that horse whims were not associated with the earlier, shallower tin workings and were only used at tin mines with vertical shafts which reached a depth beyond the efficient working of either the shamelling technique or the use of a windlass.

None of the copper mines where horse whims have been recorded were active prior to the 19th century, with the exception of Virtuous Lady. In a few cases the approximate date of the whim plats are known; Borro Wood, a copper prospect in operation in 1856 (Newman 2003, 183), South Plain (1849 – 1854), Yarner (1857 and 1864) and Holne Chase (1874-7).

The earliest documented tin mines where whims have been recorded are Furzehill (HW27-8) and Wheal Jewel (HW22). The former, although having a long career with origins in the 16th century (Greeves 1981, 319), underwent an episode of deep shaft mining in the 19th century (BI, Walkhampton). Wheal Jewel was working during Kalmeter's (1724) time but like Furzehill, was worked extensively through the 19th century too. Wheal Chance (HW8) however, is first documented in 1806 (DRO 1311M/Deeds/4/6) though lack of further documentation suggests it may have been abandoned shortly afterwards. Whiteworks, where three whim plats survive (HW14-16), is documented from 1786; in 1818, two horse whims are listed in sale particulars (Greeves 1980, 13). Eylesbarrow (HW34-8) was begun 1804 but remained working until 1852 (Newman 1999, 110). Holne Chase (HW7) is the whim that may with certainty be one of the latest examples, this mine not being started until 1874 (Newman 2006, 2).

On the basis of field evidence alone, it cannot be proved that any of the horse whims recorded were in use from the time of their introduction to the Westcountry in the 1720s because all the surviving examples are at mines that have 19th century episodes. The apparatus was certainly in general use by 1780s and became more common as the 19th century progressed. Although ideal for use in shallow or developing mines, when shafts reached greater depths, the limited capacity and operational speed of the horse whim, coupled with the cost of maintaining the horses, made them far from efficient. Deep or more productive mines would have required greater mechanization of the hoisting technology, powered by either steam or water power.

7.2.8 Water whims

The term water whim could be interpreted to mean a horse whim that was used to raise water, by means either of a rag and chain pump or by hoisting a kibble on a rope. However, the more usual usage is for a hauling device powered by a waterwheel. Attached to the axle of the waterwheel would be a cable drum or 'cage' and a system of gears allowing the cage to rotate in both directions (Earl 1968, 68). Cables would run from the cage to the poppet heads in a similar fashion to the horse whim, although the waterwheel could be sited some distance from the shaft, being located to make best use of the water supply. At Little Gem Mine the waterwheel was sited just above river level, along with two other wheels and the dressing floors, although the hauling shaft was approximately 70m to the north up a steep slope. Neither Borlase (1758) nor Pryce (1778) mentioned water whims among the devises they described and it may be assumed they were introduced towards the end of the 18th century, though at what date they were first used on Dartmoor is yet to be discovered.

Field evidence

Field remains for definite examples of water whims are uncommon on Dartmoor, only eight certain examples having been recorded. However, the recorded data has excluded evidence from Wheal Friendship where water-powered shaft haulage is well documented from early in the 19th century (Barton 1964, 86), with potential for evidence from the 1780s when the mine was first established (Hamilton Jenkin 1981, 33). Unfortunately very little of the early evidence of Wheal Friendship survives or is accessible and it has not been possible to establish details of its water-powered hoisting. In a report of 1838, it is mentioned that of the seventeen waterwheels employed by Wheal Friendship and its nearest neighbour Wheal Betsy combined, four were used for hoisting (Watson 1843, 55), which would bring the total to 12.

The pit in which the cage or cable drum was housed adjacent to the wheelpit is one of the diagnostic

Fig 7.27 Overgrown wheelpit for a waterwheel to power a whim, with the characteristic drum pit on the left hand side. Little Gem Mine.

features that confirm the use of a waterwheel for hoisting, two certain examples of which survive at Little Gem Mine and Lady Bertha Mine. At Little Gem a well preserved 7.3m by 1.1m wheelpit (WP 41) has a cable drum pit of 3.3m by 0.9m wide aligned parallel with the wheelpit approximately on its axle line (Fig 7.27). A similar configuration survives at Lady Bertha, though the wheelpit (WP 18) is much larger at 12.2m by 1.3m and the drum pit of 4m by 1.2m. At Golden Dagger's Machine Shaft, a waterwheel (WP40) located near the shafthead was almost certainly powering a whim, which accounts for the massive finger dumps of spoil associated with the shaft, there being no horse whim present. All these examples can be confidently dated to the 1870s and 1880s (Table 7.1).

It is probable, that several other wheelpits, which do not possess these drum pits may also have served as hoisting wheels. In these cases, the wall of the wheelpit was built to a sufficient height to make the pit unnecessary, or these wheels were powering conventional whims, similar in appearance to horse whims. Such an arrangement is depicted on a plan of Fowey Consols (Cornwall) that appears in De la Beche (1836). Possible examples of this arrangement include Virtuous Lady (WP23), Wheal Emma (WP11), Golden Dagger (WP40) Brookwood (WP8), East Birch Tor (WP34), and Vitifer (WP38), all of which are suitably aligned with a shaft, but with no obvious indication of pumping equipment associated. It has not been possible to date any of these water whims to earlier than 1860; the majority are much later, though the example of Wheal Friendship demonstrates the potential for early 19th-century water whims existing.

7.2.9 Steam whims

Steam power to drive whims is first recorded in Cornwall in 1784, and by the early 19th-century 'whim engines' were becoming commonplace at mines of greater depth where horse whims were too slow to work efficiently (Barton 1969, 185). The earliest Cornish type whim engines worked on the same principle as pumping engines, with a vertical cylinder mounted inside the engine house driving a rocking beam or bob. Outside the building, the reciprocal motion of the engine was converted to rotational by means of a crankshaft from the beam and a flywheel, attached to the axle of which was a cable drum or cage, from where the cables extended to the shafthead.

Field evidence (Table 4.3)

Although several additional whim engines are documented, only four engine houses recorded within the study area have structural evidence which defines them as once containing Cornish type whim engines, each having evidence of the external flywheel and cable drum pits. All are at either copper or lead mines on the peripheries of the moor. The clearest example is at Brookwood Mine (Fig 7.28) which although the building only survives as a stump has clear diagnostic features on the exterior, with the flywheel and cable drum pits surviving and the crankshaft loading, a platform which absorbed the thrusting motion of the crankshaft, on the exterior of the bob wall. This powered hauling in Martin's Shaft, over 210m away, where a circular plat (HW3) also survives (Fig 7.29). This may have accommodated the cage powered by the steam whim or a conventional horse whim, possibly preceding the former. At Arundell Mine, the whim was housed on a separate structure at the shafthead (Fig 7.30), powered probably by

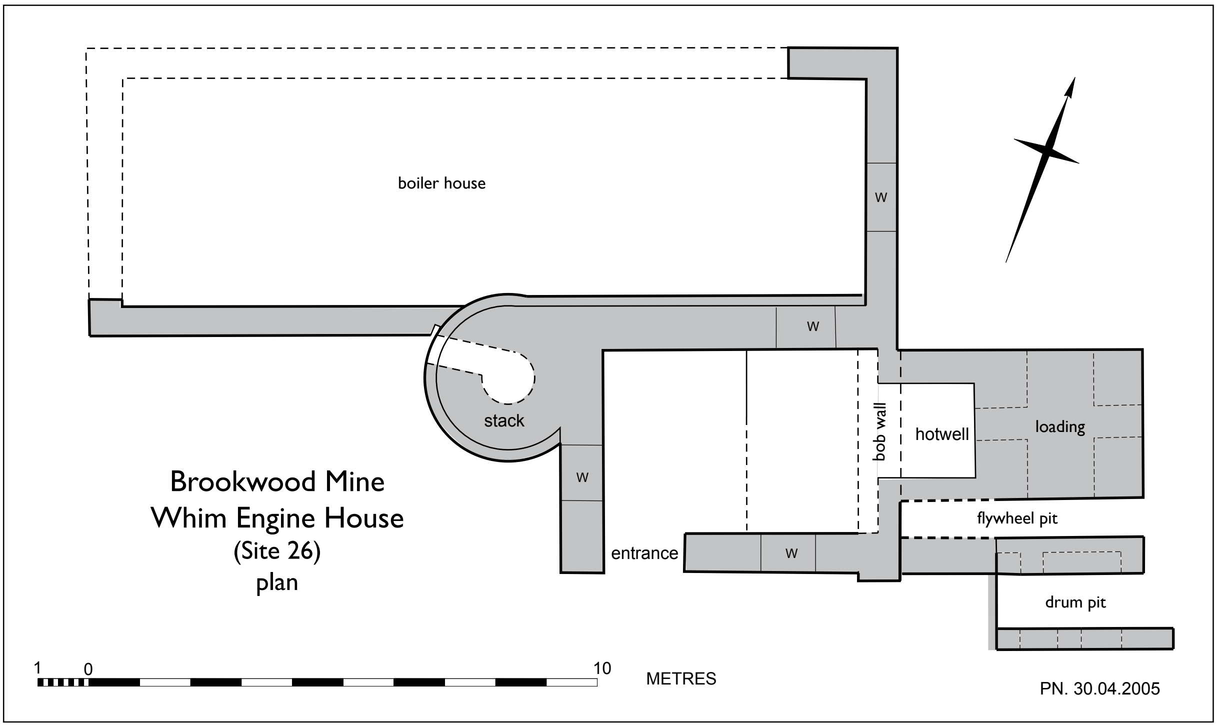


Fig 7.28 (above) Ground plan of the ruined whim engine house at Brookwood Mine (EH 18). Diagnostic features that confirm its former status as a whim engine being the flywheel and drum pits.

a small horizontal engine of the type depicted in Perran's Foundry Catalogue (nd, 9). At Silverbrook, the abandoned mine plan (AMP R54C) shows an engine house, which shared power between a crusher housed in a separate building and a winding drum mounted on the exterior of the engine house. Unfortunately the buildings are collapsed to just above foundation level and the section drawing on the plan is the only evidence for this arrangement.

An alternative to the standard beam engine was the horizontal engine, favoured towards the end of the 19th century and, according to Barton, after 1887 all whim engines erected were of the horizontal variant, with the cylinder lying on its side (Barton 1969, 205).

The concrete base of a horizontal whim engine and a chimney survive at Ramsley Mine, installed at around 1900 (Greeves 1995, 58), and at East Lady Bertha Mine where a rectangular stump of a stone building probably housed the 14-inch horizontal engine listed in sale particulars in 1861 (*MJ* 2.2.1861). In this case the chimney, clearly marked on the OS map of 1884, is no longer standing.

7.2.10 Capstans

The capstan is a man-powered, horizontally rotating hauling device used to hoist or lower heavy pieces of equipment in shafts. Although working on a similar principle, the capstan provided an additional level of control that could not be achieved by the horse whim. William's Perran Foundry catalogue (nd) (Fig 7.31) has an illustration of one of these devices and suggests specific uses including:

> *Raising or lowering heavy weights in Shafts, such as Pumps, H and Door Pieces, parts of connecting Rods… Cast Iron Axles..*
>
> (Trevithick Soc. 1989, 15).

Of the five hoisting devices described by Agricola, the capstan is not one of them and it has to be assumed that its introduction to the mining world came later than the 16th century, possibly with the introduction of heavy iron components for the pumps. Capstans were certainly in use by 1778 when Pryce depicts one on his cross-section of Bullen Garden mine (Pryce 1778, Pl. 4) though it does not resemble later depicted examples, appearing more like a small whim.

The Williams catalogue illustration shows a horizontally rotating eight-sided conical drum with a central vertical axle supported between a bearing on the ground (not shown) and a horizontal fixed beam above, which in turn is supported above the ground by legs and timber braces at each end. A long bar, which was mortised into the axle, extends horizontally through each corner of the drum, so that a team of

---

Fig 7.29 (overleaf) Plan of earthworks and ruined structures at the central area of Brookwood copper mine. Showing the two main shafts, the pumping engine house above Engine shaft, the whim engine house, which is likely to have hauled in Martin's shaft. Also wheelpits, waste heaps and the ruined dressing floor.

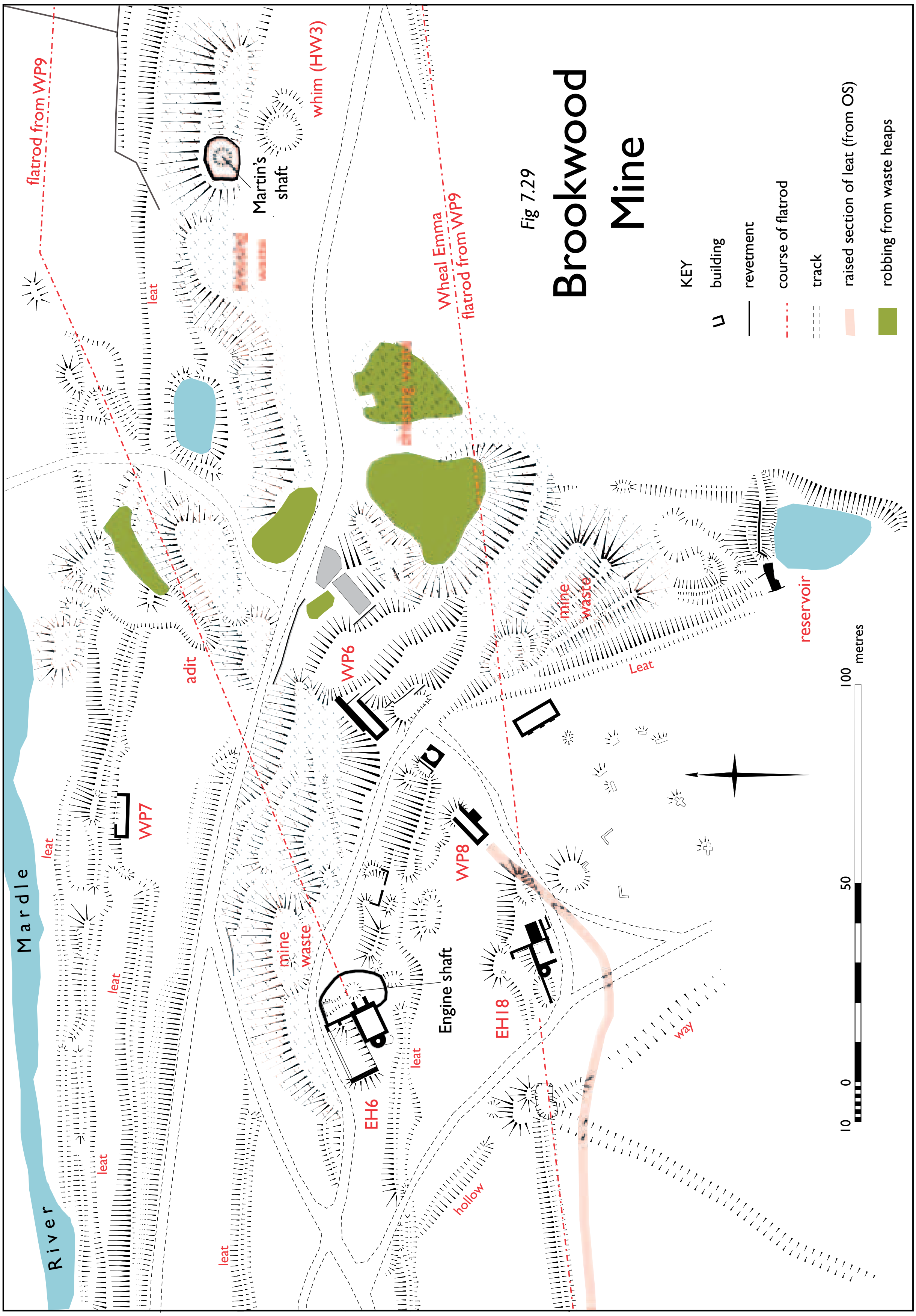


Fig 7.29
Brookwood Mine

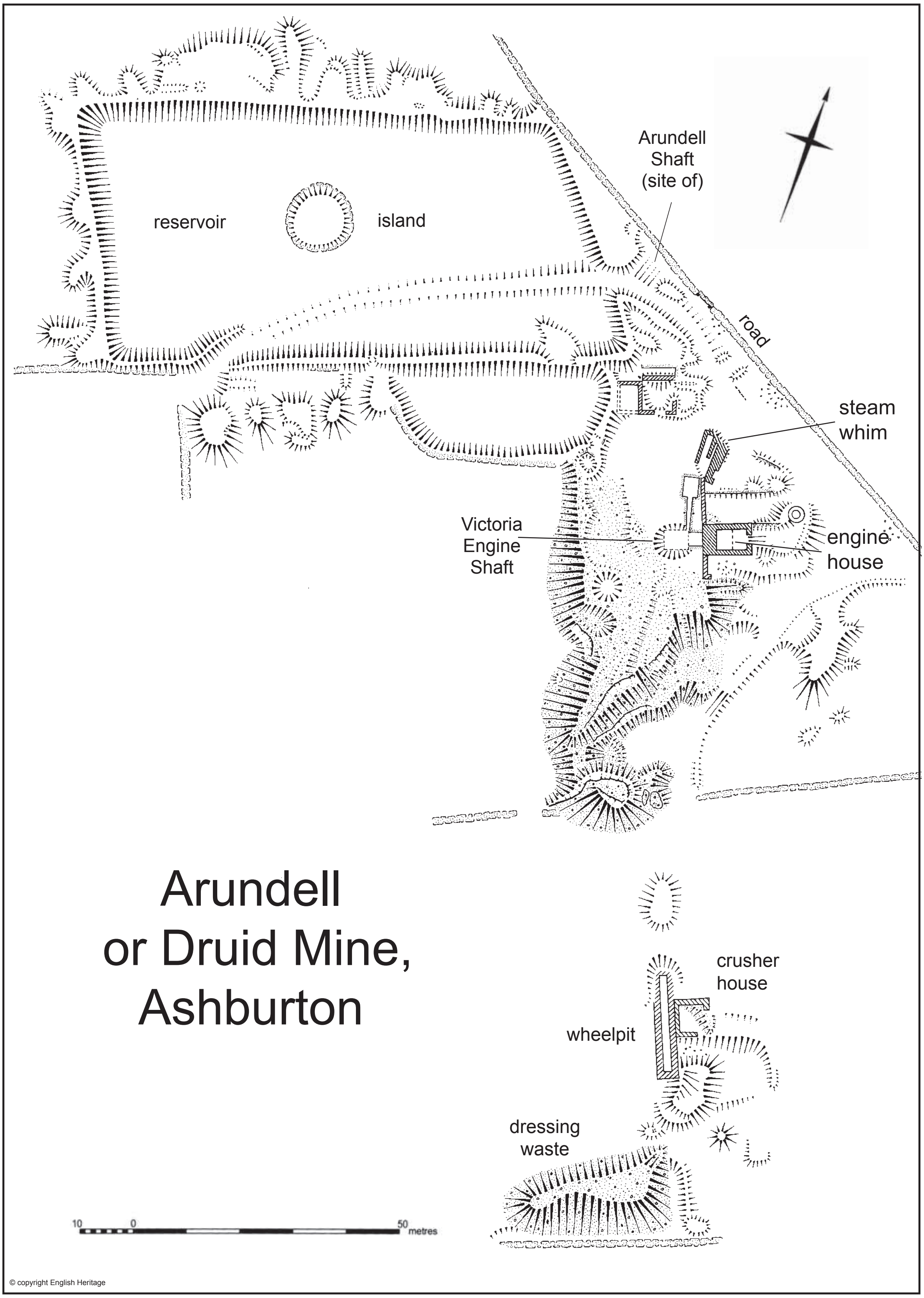


Fig 7.30 Earthwork plan of Arundell Mine showing the large earthwork reservoir which stored water for the 60ft waterwheel, the engine house sited above Victoria Engine Shaft; a large spoil heap of mine waste; crusher house and dressing waste.

Fig 7.31 A man-powered capstan. From the Illustrated Catalogue of William's Perran Foundry Co. of the 1870s.

men could control the device by gripping the bar and walking to rotate the drum in a clockwise or anti-clockwise direction, depending on whether raising or lowering.

Capstan pits – field evidence

The field evidence of a capstan is similar to that of a whim, and one could easily be mistaken for the other. It consists of a circular level-topped platform (plat), on which the device rotated, its vertical axle supported by a bearing or mellior stone centrally sited. However, the main difference is that the cable drum was partially or completely set into the ground within a masonry-lined pit at the centre of the circle, the capstan pit, which housed a mellior at the bottom. The cable ran from the drum, horizontally in a channel or stone conduit, which traversed the radius of the circular plat. Where visible these survive as an earthwork channel cut into the plat.

Two examples demonstrating most of these details were excavated at Esgair Hir, lead and copper mine in Cardiganshire and published in 1983. The excavation revealed the melliors in the base of the capstan pit; in one case this was made from a flat stone with a bearing formed by a shallow blind hole. In the other the bearing was cut into a solid piece of timber. A wooden roller was also found *in situ* at the end of the cable conduit, over which the cable had passed before descending the shaft. (Palmer 1983, Plates 3, 4, 11 and 12).

Field remains of eight capstan pits have been recorded on Dartmoor, the examples being found at both tin and copper mines. Five of the eight are sited adjacent to shafts for which it can be confirmed, either from documentary or field evidence, were once equipped for pumping, and four of the shafts were also equipped with other hoisting devices, such as water- or horse-powered whims. The plat, like those associated with horse whims, were either artificially raised by constructing a flat-topped mound of earth, where the ground is more or less level, or they were created by cutting a stance into the slope of a hillside. The example at Whiteworks falls into the former category. The *c.*10m-diameter platform is raised approximately 1m above the ground and the centrally placed capstan pit has a diameter of 2.5m, with a stone lining around the interior circumference surviving in fair condition. The capstan could be set some distance from the shaft as at Virtuous Lady Mine, where although the diameter of the plat is only 4.4m, the channel which accommodated the cable to the shaft is 11m long. The capstan pit on this example has slightly battered stone lining giving it a conical profile.

Archaeological evidence of capstan pits is an important diagnostic feature in identifying pumping or engine shafts where no other clues survive. At Whiteworks for example, at one of the shafts, no bob pit survives but a well-preserved capstan pit confirms its status as an engine shaft.

7.2.11 Adits

Adits are horizontal tunnels driven into a hillside and have their origins as a means of draining water from the working areas, but were also used to provide level access to underground sections of the mine. When a mine was worked to a reasonably shallow depth, it was possible to drive an adit beneath the workings, commencing from the lowest possible point above river level. Water could then drain through the adit and such mines are referred to as 'free draining' (Fig 7.32). The topography of Dartmoor is particularly suited to the use of drainage adits, where steep and numerous hills allowed for relatively short adits, reducing the work involved in driving them. This fact was celebrated in 1787 by William Warren, in his pamphlet promoting a new tin mining company, in which he stated that this was one 'superiority' Devon has over Cornwall:

> *The metallic Country of Devon being mountainous, and of greater Number, than those of Cornwall, affords speedier Levels or Adits for draining the mines, and these of greater depth.*
> (Warren 1787, 2)

Thus Dartmoor's mines could often be drained more cheaply as moderate depth could be reached before pumping became necessary. The comparison with Cornwall is significant too; in the low-lying, flatter districts of Camborne, many mines were concentrated into a relatively small area where the driving of one large adit, the County Adit, commenced in 1748, partly solved the problem of drainage. (Buckley 2005, 99). This took 18 years to complete at great expense and was only worthwhile in this rich ore-bearing district so densely packed with mines.

Adits were also used as a route for removal of waste and ore via tramways or in barrows and access for the miners was easier via an adit where possible, giving entry to underground sections of the mine and lessening the need to descend or ascend ladders. Prospecting for lodes was also carried out using trial adits (see above).

The origins of the drainage adit as a mining technique is obscure, but was certainly in use in Roman times: examples at Doluacothi gold mines in Wales are traditionally understood to be of Roman date.

Although dating evidence of 1st century BC is available from Dolaucothi, the adits themselves have not yet been securely dated (Burnham 1994, 42). Adits or 'tunnels' linked to shafts, were standard practice by the time of Agricola in 1556 (Hoover & Hoover 1950, 102). Lewis, writing specifically of tin mines, considered that the introduction of the adit, could not be traced back any further than the early 17th century (Lewis, 1908, 11) and although the Cornish writer Norden mentions the problem of flooding in tin mines in 1585 (Norden 1585, 14), it was Carew in 1601 who first described the use of 'addits' to 'give passage' to the water in Westcountry mines (Carew 1601, 11v).

The anonymous writer of 1671 observes that 'if this conveniency of an adit may be had, then our water injures us little' (Anon 1671, 2106). Like the shafts described above, the practice of driving adits was firmly established by the commencement of the study period and continued to be one of the key features of all mines thereafter. However, the driving of adits through hard rock would have been constrained in the period before the introduction of gunpowder, when hand tools and possibly firesetting techniques were the only ways of breaking the rock. For small scale shallow mines the choice of low-tech pumping devices such as the rag and chain, may have been more cost-effective than driving a deep adit through granite. Dating the origin of an individual adit is only possible if documentation survives which specifically describes it being 'driven' and no assumption should be made based on the general dating for the site; an adit commenced in the first few weeks of a mine's existence may have remained in use decades later. Once in existence adits were reused when cleaned out or extended, an activity frequently referred to in documentation (i.e. Dartmoor Forest Mine. *MJ* 04.01.1851). For undocumented adits there is a real possibility that their origin lies long before the recorded period that a mine was worked.

Not all mines possessed an adit: at Queen of the Dart which is located on the flat ground, level with the river bed of the Dart, it is recorded that pumps, powered by a waterwheel raised water to surface in the engine shaft (*MJ* 3.12.1854), and at New Victoria Mine (formerly Arundell Mine) which reached over 90 fathoms depth, no adit is depicted on the section drawing of 1871 although many levels are shown (AMP R100B).

Field evidence

The quality of surface evidence for adits varies widely depending on location, either on the extremely wet granite uplands, or on the Metamorphic Aureole, and whether they have been deliberately blocked after abandonment or left open. Many adits do remain open, continuing to drain the disused mines and provide access for underground exploration, although underground recording has been beyond the scope of this thesis. The majority of these open adits lie in the private wooded areas surrounding the upland, whereas in the moorland areas most are blocked. There are two main reasons for this: firstly, adits were often backfilled after abandonment, especially on the commons, where they were a threat to livestock. In some cases this is documented, as at New Vitifer Consols where, in 1877, the Duchy Agent paid for the

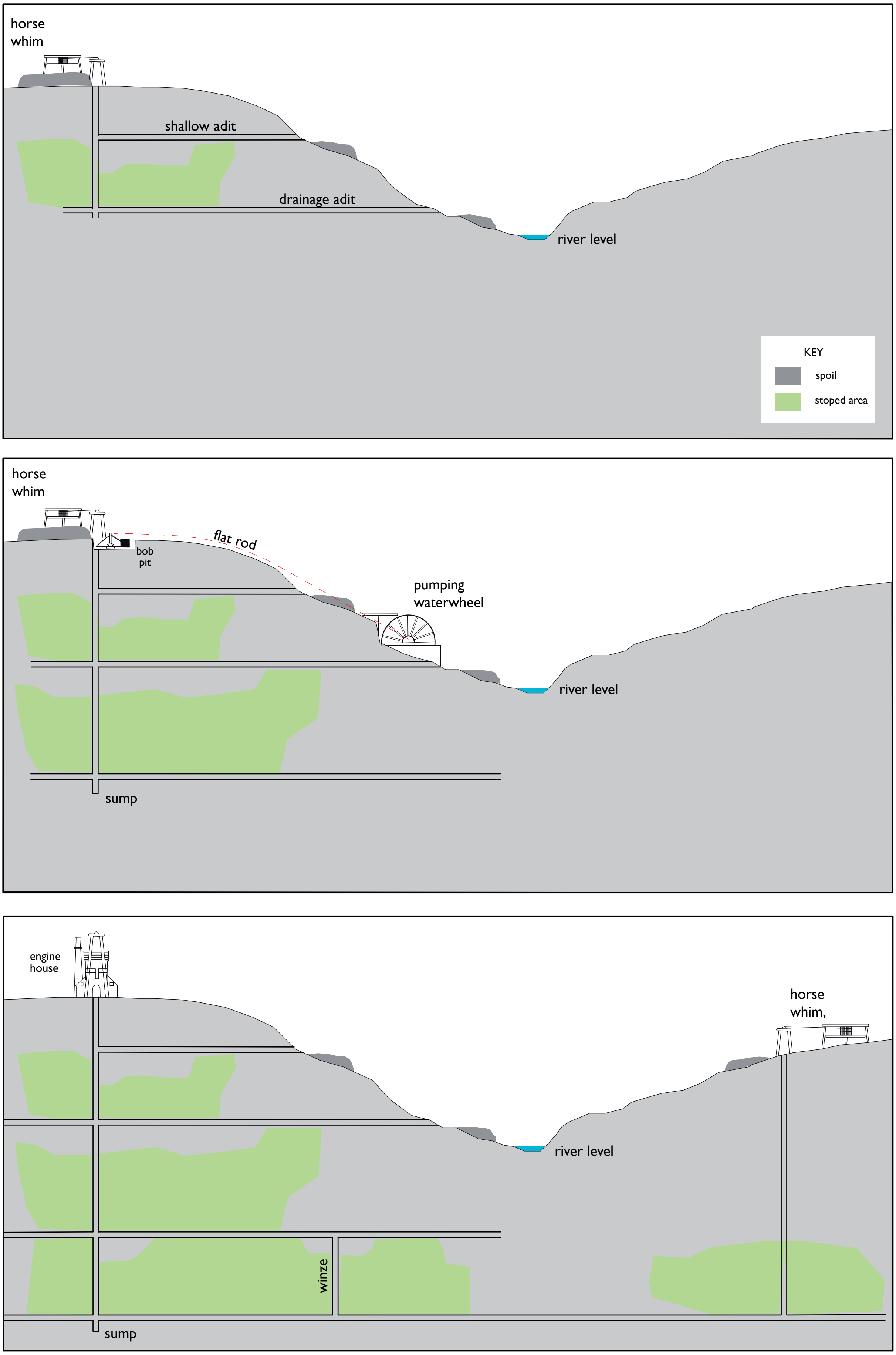


Fig 7.32 Schematic reconstruction showing the difference underground between shallow free-draining mines (top) and those of an intermediate depth requiring mechanised pumping powered by waterwheels (middle) and a deeper, more extensive mine pumped and hauled using steam engines, though with a horse whim hauling on the exploratory shaft on the right (bottom). Few Dartmoor tin mines were of the third type, especially on the granite zone, but several copper mine around the edge of the moor fit this category.

adits to be backfilled (Passmore 1997, 30), but for many mines, this event went unrecorded. Other adits are choked by boggy vegetation that has built up around the portals due to the extremely wet conditions. This in turn causes the water to back up and flood the adits.

In such cases the adit portal itself may be no longer visible, its position being identified by a linear spread of bog and rushes, and an unnatural occurrence of water seeping from the base of a hill. Often however, the external lobby of the adit survives as a rock-cut gully leading up to the portal. The length of the open gully varies depending on the gradient of the hillside. On a steep or near vertical slope there is often no lobby at all, but where the gradient is slight, the level cutting needs to run into the hillside for some distance before it is deep enough to go underground. At Wheal Jewell an adit is, unusually, sited fairly high on the hillside where the gradient has started to level out, necessitating a lobby of almost 70m in length; large enough to be depicted on the 1st edition OS 25-inch map of 1886. A trial adit at Whiteworks, similarly placed higher up the slope has a gully of approximately 40m long (Fig 7.2). Adits are frequently located within or near openworks, demonstrating the later underground working of a lode previously exploited by opencast techniques. A clear example of this occurs at Henroost tin mine, where the adit lies in the lowest part of the openwork. The portal is blocked, though visible, and a long straight cutting with revetted sides runs along the base of the openwork to accommodate the tramway, established to remove the ore (Fig 7.33). At Holne Chase tin mine, an adit whose open portal is located 20m downhill from the older openwork, was driven below and to one side of the pre-existing working.

7.2.12 Spoil heaps

Waste material cut during the progress of underground mining, was variously referred to as gangue, deads and spoil, and when brought to surface, was systematically disposed of on heaps, mounds, dumps or burrows.

Spoil heaps associated with adits

At relatively shallow mines and mines under development, where the drainage adit represents the lowest feature of the mine, the option to transport material horizontally via the adit was available, and evidence exists at several small mines on Dartmoor. Caroline Wheal Prosper, Little Gem and Walkham United all have substantive spoil heaps near the adit mouth, usually transported by trams or barrows to form finger-shaped dumps. In some cases this may represent material removed while driving the adit as well as waste material or deads excavated from the underground stopes. Linear dumps of spoil are also often found extending from the portals of exploratory adits and represent only the material arising from driving the adit itself. Examples are Bushdown Mine, an unnamed mine on Cudlippton Down (Fig 7.34) and Devon Copper (Fig 7.35).

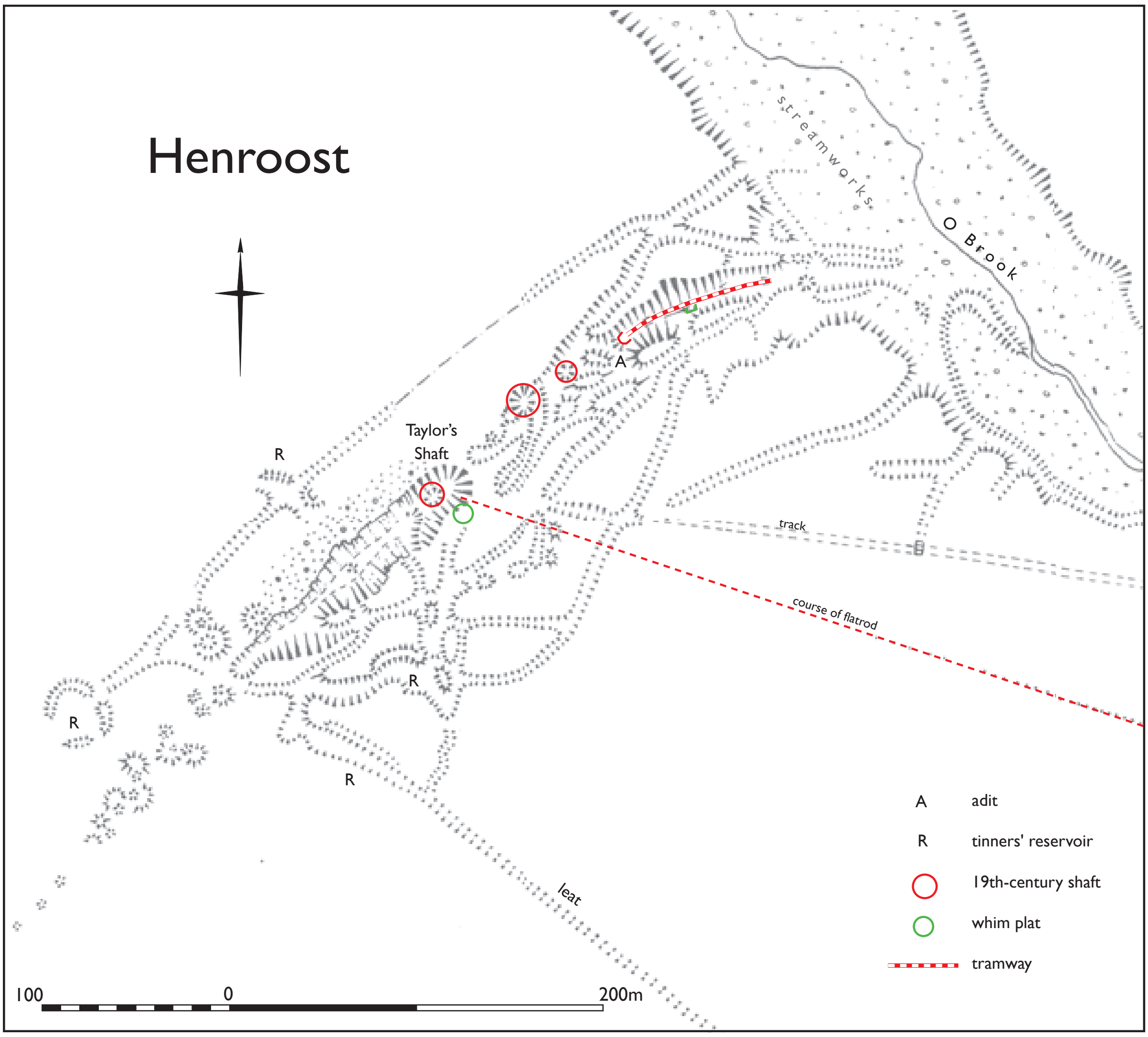


Fig 7.33 A 1:2500 scale plan of Henroost, part of the Hexworthy Mines, showing the location of 19th-century shafts sunk into the much earlier openwork and the course of a tramway running along the base of the old openwork as it emerged from a blocked adit that had been driven into the working.

Spoil heaps associated with shafts

At more developed mines with deeper shafts, hauling within the shaft was necessary using one of the devices described above; firstly to raise the deads arising from sinking the shaft itself, but also the materials emanating from levels and stopes below adit level (Fig 7.32). The primary evidence for the hauling of deads is large spoil heaps either at, near to, or associated with the head of the shaft. The spoil could be dumped around or near the rim of the shaft, as at Gibbet Hill, Huntingdon, Eylesbarrow, Whiteworks, Arundell, forming flat-topped heaps. Alternatively, having been raised to the surface, the spoil would be trammed onto finger-shaped dumps some distance from the shaft as at Brookwood (Fig 7.29), Emma (Fig 8.25) Walkham and Poldice, and Hexworthy mines (Fig 7.36). The latter method of disposal occurs more frequently at small to large scale productive sites, whereas the former is found at all categories of site where shaft hoisting is evident, including those never developed beyond a prospect, such as South Plain Wood Mine and Wheal Surprise.

Fig 7.34 A sizeable flat-topped spoil heap made up of mine waste from an unnamed developed prospect on Cudlippton Down. The material emanates from an adit, whose open access gully is visible in the foreground.

Although the extent of waste heaps can provide some indication of the duration and success of a mine, this can only be approximate as much waste was disposed of below ground and as a mine became more developed so the below-ground space for waste increased. However, this could only occur where worked-out stopes (underground voids) existed and therefore applies only to productive mines or mines which were developed extensively underground. Arundell copper mine reached a depth of 90fthms and had two shafts and eight underground levels (AMP R100B), though very little copper production is recorded (Newman 2003, 173-218). The result of all this development was a sizable spoil heap at surface (Fig 7.30). At some mines waste was disposed of in old openworks; such is the case at Ringleshuttes where, one openwork has been partly backfilled by waste raised up a nearby shaft. Taking these points into account, analysis of the surface waste of mines in the study area has indicated that, with only a few exceptions (Hexworthy [Fig 7.36], Golden Dagger and Vitifer [Fig 7.8]), tin mines located on the granite mass of Dartmoor, have limited waste heaps strongly suggesting limited underground development. All mines in their development phase had to bring material to surface when sinking shafts or driving adits and a lack of associated spoil indicates minimal development. Within the Metamorphic Aureole mines with much larger waste heaps do exist, reflecting the greater depth required to reach paying ground. Tin mines of this larger scale are rare on the Metamorphic Aureole but Little Gem, Owlacombe, Walkham Consols, Wheal Franco (the remains of latter now mostly dispersed) and Sortridge Consols are the exceptions. The most extensive waste heaps are associated with copper mines at Wheal Emma (Fig 8.25), Brookwood (Fig 7.29), Wheal Friendship, Ramsley, Lady Bertha and Belstone Consols.

Significant spoil heaps associated with shafts tend to occur at the same sites as where steam, water or turbine powered hoisting devices were in use such as Hexworthy, Brookwood, Little Gem, Walkham and Poldice, Arundell and Golden Dagger, whereas spoil heaps raised using horse whims are usually, though not always, more limited in scale.

7.2.5 The reworking of pre-1700 mines

In Chapter 5 it was argued that a proportion of 18th and 19th century mining companies attempted to rework lodes which had been previously exploited at shallow depth using less developed technology by the 'old men', a term which was used when referring to any working abandoned before living memory. This behaviour is manifest in the field evidence as recorded in Tables 6.1 and 6.2, which show that most tin mines and some copper mines of the study period followed this pattern. Much of the evidence for deeper mines discussed above therefore, sits alongside or overlies the evidence of earlier activity.

Openworks, which as a class of tinworking technique according to Borlase and Pryce were long abandoned by the mid-18th century, were frequently reworked by sinking shafts either into the floor of the old working or adjacent to it, in the hope of meeting the lode at greater depth. Examples of this activity can be seen at all the major areas where openworks exist, including Hooten Wheals, Ringleshuttes (Fig 7.7), Wheal Mary Emma (Fig 7.11) and the Birch and Tor Vitifer Mines (Fig 7.8). At the latter, there is surface evidence of at least 50 shafts that are demonstrably later than the openworks, accompanied by the dumping of spoil, wheelpits for pumping and hoisting waterwheels, flatrod systems all associated with later period mining, which is documented at this site from the 1750s (Hemery 1983, 614) (Fig 7.24).

For reworked pit workings the evidence is more subtle, because shafts and pit works were very similar techniques, varying only in scale and reflected in the field evidence. However, the deeper shafts, which were typical of the later phases, have commensurately larger spoil collars or finger dumps from which they may be recognized, often overlying the remains of earlier phases. Wheal Prosper (Fig 7.10) Wheal Fortune and Huntingdon Mines (Fig 7.4) all demonstrate this phasing.

7.3 DISCUSSION

Archaeological evidence for the working of tin lodes on Dartmoor and the technological inference which may be drawn from it, conforms with the two main episodes of industrial activity as defined by the documentation discussed in Chapter 4, which are discernible through morphological differences in the field remains. The first episode had origins in at least the 15th century, though probably earlier, and

Fig 7.35 (overleaf) Devon Copper Mine. A developed prospect with a shaft and adit, both with moderate spoil heaps, and a wheelpit to accommodate a pumping wheel. There is no evidence of a dressing floor. (nb the dam and weir to the north of the mine are not associated)

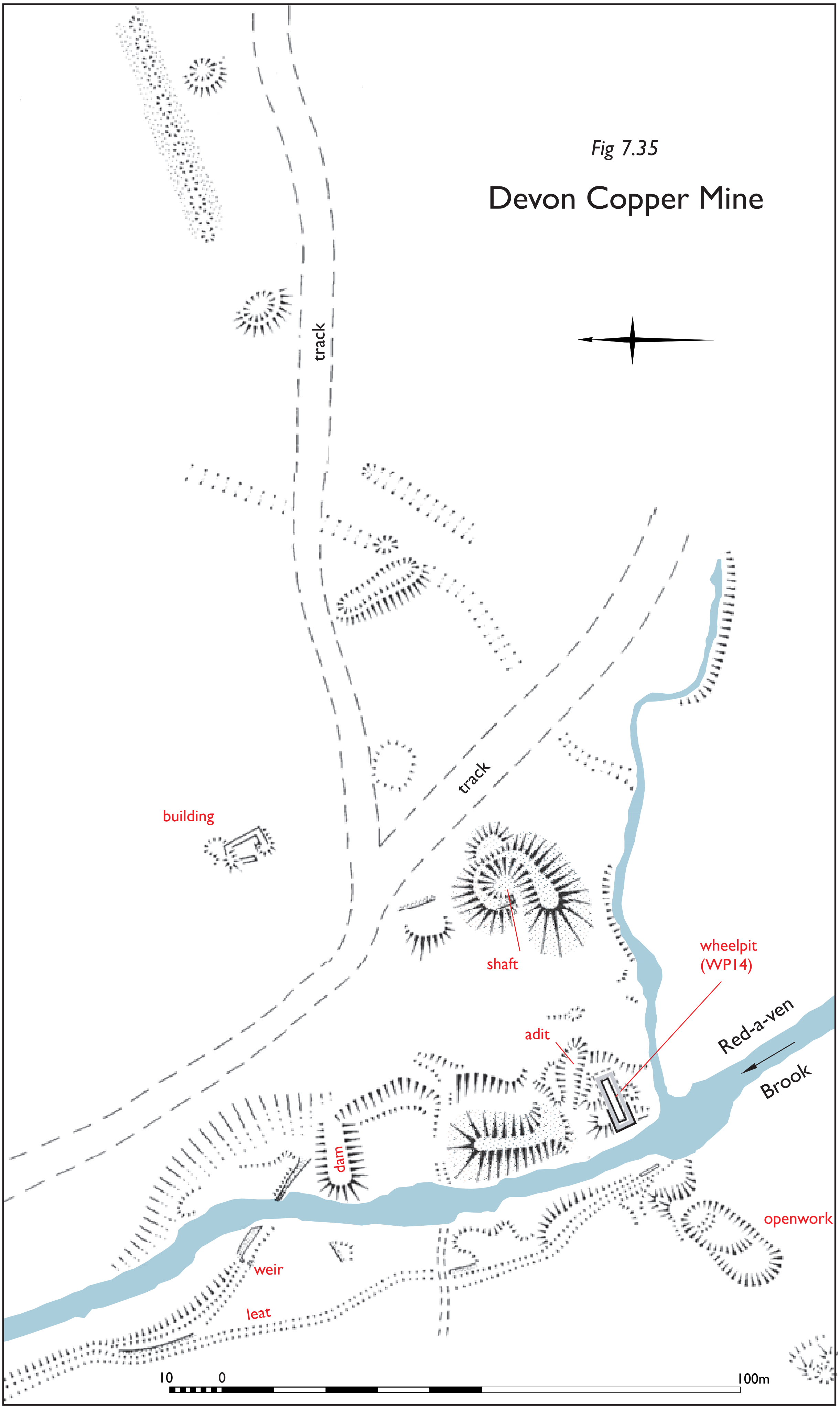


Fig 7.35
Devon Copper Mine
track
track
building
shaft
wheelpit
(WP14)
Red-a-ven
Brook
adit
dam
openwork
weir
leat
10
0
100m

Fig 7.36 A large finger dump of mine waste emanating from Lowe's Shaft at Hexworthy Mine. The flat upper surface would have accommodated a tramway.

extended into the late 17th century and a period of decline. It is characterised by the exploitation of the upper sections of lodes using openwork and pit working techniques. Although transition was no doubt gradual, after 1700 and the second episode, with which this study is mainly concerned, underground mining was the dominant technique. However, a revival in the fortunes of Dartmoor mining did not occur until later in the 18th century from which phase the first dateable material is available although these temporally separate technologies often occur at the same location indicating reworking of abandoned mines. Extraction using openworks, for which extensive evidence of probable post-medieval date survives, was certainly obsolete by 1700. Pit workings may also have been considered outmoded by that date, but documentary evidence has so far failed to confirm this. As for the use of surface prospecting using trial pits, if not obsolete, this method was certainly in decline at a time when methods to explore lodes at greater depth were being developed. By the late 18th century, prospecting for tin may well have relied totally on the evidence of pre-worked lodes, as discussed in Chapter 5, and only the discovery of copper lodes relied on prospecting.

The bulk of the field evidence that survives, where documentation can be associated, represents the period between about 1780 and 1900 with outliers at both ends of this range; remains include evidence for pumping, hauling and dumping of waste at mines which worked tin, copper or both. Although shafts and adits cannot be dated without documentation, available surface evidence for hauling and pumping is likely to date from no earlier than the closing decades of the 18th century, coinciding with a revival of tin mining and an acceleration in copper production. However, the great majority of the evidence discussed above represents the work of 19th-century mines, coinciding with periods of prosperity outlined in Chapter 4, and funded from capital raised by adventurers through the cost-book companies and, later, limited liability joint stock companies, who had the capital needed to invest in the development (Chapter 5).

The generally small and undeveloped scale of underground activity at many Dartmoor mines is foremost among inferences which may be drawn from this surface evidence. On the granite mass in particular, the limited depth of several mines is evident from small spoil heaps at both the sites of adits and shafts. Only a limited number of mines have substantial evidence of spoil. Although it is known that productive mines would dump waste in worked out stopes underground, this would only account for some of the absence at surface. Driving adits and sinking shafts through dead ground during initial development needed waste to be brought to surface. The shallow mines that this evidence represent may potentially have produced some good quality ore but that could never have been enduring.

Within the Metamorphic Aureole, lodes were generally encountered at greater depth and larger spoil heaps are more common; the lower Walkham valley mines for example (Little Gem; Walkham United; Poldice; Sortridge Consols) all have sizeable spoil heaps though undeveloped mines have also been identified in this zone (Wheal Rose). This evidence cannot always be relied on as an indicator of productivity however, as in the exemplar of Arundell Mine.

Limited depth is also evident through the type of technology used for hauling in shafts. The horse whim is by far the most common hauling device with 48 examples recorded within the fieldwork sample against eight potential water whims and four steam whims. The limitations associated with the horse whim are not recorded but their maximum working depth and efficiency would have been a constraint to productivity and were only truly viable at developing mines and very small-scale productive mines.

By the early 18th century some of Dartmoor's mines were sufficiently deep to require pumping installations, which were necessary to prevent underground flooding. Whereas in Cornwall, steam engines were introduced for this purpose in the 18th century and their use burgeoned in the 19th, on Dartmoor water wheels continued as the preferred technology at all but a very few mines. The reliance on water wheels meant that flat-rod systems were numerous at Dartmoor mines and the very large waterwheels that powered them must have been a common feature of the 19th-century landscape. This fact and some suggested reasons that lay behind it will be discussed in Chapter 9. Although the field evidence has demonstrated that water-powered pumping systems were a key component in the viability of some Dartmoor mines, the proportion of mines possessing these systems (about 25%) also confirms that the majority were never worked to a depth greater than the local water table. The lodes were either too shallow or too poor to justify this expense.

In reconstructing the late 18th- and 19th- century mining landscape of Dartmoor from the archaeological evidence of extractive activity alone, the main conclusion has to be that the majority of tin mines were small in scale, even those which proved moderately enduring and productive. Though larger concerns did exist, especially copper mines, at the other end of the spectrum, they are far outnumbered by those for which field evidence implies they were little more than prospects (Tables 6.1; 6.2). Although choices of technology were partly influenced by environmental factors, it was mostly undeveloped compared with Cornish mines, the limitations of horse-powered hauling and water-powered pumping, when required, proving to be adequate for the level of activity at the majority of mines. Steam power was justified at very few.

Once ore was raised it had to be processed or dressed. The archaeological evidence for ore dressing offers a different perspective and it is the surface remains of these operations that form the next topic for consideration.

CHAPTER EIGHT

SURFACE ARCHAEOLOGY: DRESSING ORE

8.1 DRESSING ORE

8.1.1 Background

Once raised to surface metallic ores need to undergo a series of refining processes before being of suitable purity for smelting. For the metals considered in this thesis these processes took place on the surface, therefore all archaeological evidence is accessible within the limitations of safety. As a corollary the processing of ores can be more fully recorded through surface investigation than extraction and developments in technology should be evident through comparative analysis of field remains, aided by the documentary record. However, many aspects of ore processing described by contemporary writers of the entire period involved the use of portable apparatus or timber structures and machinery, most of which are unlikely to have left a perceivable archaeological record; therefore only evidence of processes which survive as structural or earthwork, or in some cases residual remains, are discussed here. Even in these cases the apparatus has been removed and the evidence comprises only the groundwork that was created to accommodated them.

The processing of metallic ores is normally referred to as 'dressing', and its primary purpose has been no more succinctly expressed than by Lock in his 1890s treatise:

> *The object of dressing ores is to separate the useful from the useless portions, and to sort the valuable minerals from each other. It should be carried out as near the mine as possible, to avoid carriage of worthless material. Water is essential, and the floors should be arranged so that the matters can be moved forward in a measure by their own specific gravity.*
>
> (Lock 1890, 338)

Collectively the worthless materials are known as 'gangue'.

8.1.2 The dressing processes

Essentially there are four processes that apply to copper and tin, for which archaeological evidence is available to a greater or lesser extent:

Sorting – initial separation of good ore from lower grades and waste; often known as 'picking'
Crushing and Classifying – reducing the ore to a suitable size for refining
Concentrating – removing impurities by settling out gangue in water
Roasting – converting sulphides to oxides and **Calcining** (removing impurities) in a furnace

However, at a practical level, the differing properties of copper and tin and the different grades and character of each ore type meant that many separate and varying processes existed within these three basic principles. It was at the dressing stage that the major differences between tin and copper mines become most apparent.

Previous studies

Previous comparative studies for the dressing processes have been undertaken by Michell (1978, 25-52), who examined the dressing of tin and copper in the period 1600-1900 in Cornwall using only historical sources, and Palmer and Neaverson (1989, 20-39) who compared Cornish tin dressing with that of Welsh lead, focussing on archaeological evidence of mines of the 19th century. No study has previously examined the Devon evidence for this period.

The latter authors when explaining their methodology, remarked that the historical approach to this subject alone would give a 'misleading impression of the scale of change' because:

> *Contemporary technical literature emphasises the adoption of new techniques but, understandably, makes little reference to the continuation of old and tested methods*
> (Palmer & Neaverson 1989, 20).

It is true that many of the available sources in which dressing is described come from technical journals or books written specifically to explain mining methods considered 'modern' at the time of publication (e.g. Agricola 1556; Pryce 1778; Henwood 1832; Henderson 1858; Ferguson 1878; Lock 1890; Davies 1894; Truscott 1923), but may not reflect changes on the ground at all mines. However, many other commentaries come from the observations of non-specialist writers with some mining knowledge, when visiting Westcountry mines (e.g. Kalmeter 1724; Angerstein 1758; Hatchett 1796; Swete 1796; Lysons 1822; Le Messurier 1967).

One complication when reconciling the contemporary published account with the field evidence is that contemporary descriptions of processes often describe best practice at high output mines producing good grades of ores, whereas many mines were small in scale working marginal grades where best practice may not have been affordable or necessary. There is also the problem that many of the mines of the Metamorphic Aureole were mixture mines, exploiting, and therefore dressing, several types of ore as well as arsenic, which became an important secondary product during the 19th century; differing dressing techniques may therefore have occurred concurrently or chronologically separately at the same site (e.g. Lady Bertha Fig 2.2). A further consideration when using these references is that, even within Devon and Cornwall, practices certainly varied between districts. This is a matter which is complicated for Dartmoor because so few of the written sources specifically mention this district, particularly during the 19th century, most being written from Cornish examples.

8.1.3 Historical context

In a European context individual dressing techniques were described as early as 1556 by Agricola (Hoover & Hoover 1950). Carew provided information on Cornish tin dressing and for Devon and Cornwall the anonymous writer of 1671 provides much detail on this topic (Anon 1671). Borlase (1758) was the first Westcountry writer to discuss the production of tin, copper and lead in a general fashion but it was Pryce in 1778 who provided the first technical guidance on the dressing and assay of tin, copper and silver-lead ores in a Cornish context. Writing 54 years later, Henwood reflected on the work of his two predecessors and stated that:

> *Considerable modifications and improvements have been introduced, and although the principle on which the operations are conducted is nearly the same, the mode of applying it is in many cases very different*
>
> (Henwood 1832, 145)

In 1858 Henderson mentioned how 'few improvements have been made within the last few years….and the able descriptions given by Mr Henwood leave little to be desired' but went on to provide information on several 'new' developments (Henderson 1858, 3).

Ferguson introduced his paper in a similar vein in 1873, claiming:

> *The processes of Dressing Tin and Copper Ores have continued almost stationary for a long period and the mechanical appliances employed have been of a very simple and crude character*

Ferguson also described 'machines of improved construction' (Ferguson 1873, 119).

The unwitting testimony revealed through a collective analysis of these pieces is that although the writers were keen to highlight the progressive nature of new development, the basic principles of tin dressing had changed little since the time of Carew and the methods for all metals described by Pryce had remained unaltered over the *c.*120 years they cover; only the scale had increased. Change was concerned only with efficiency and improvement of existing technology; truly 'new' technology was introduced only rarely.

8.1.4 The different properties of the ores

In its lode form the oxide of tin, Cassiterite (SnO^2), is finely disseminated within the gangue of the matrix and the whole needs to be reduced to a fine sand before separation and concentration can be achieved in readiness for smelting. The main ore of copper is Chalcopyrite ($CuFeS^2$), a sulphide, which was often found in a more massive form and when rich, needed little or no dressing to separate the ore but when of poorer quality some reduction and concentration would be needed. Also, sulphide ores need roasting immediately prior to smelting to convert them to oxides, which meant that in general, less of the work was carried out by those who mined copper than those who smelted it. Tin was also often roasted, or rather calcined, but in this case it was to remove impurities and was undertaken as part of the dressing process at the mine, so the product which left the mine for the smelting house, known as ‘black tin’ was ready for smelting. This difference in the extent and effort of the dressing between tin and copper was outlined by Henwood in 1832, who also observed that as a result of these differences:

> *..although a given quantity of average copper-ore, as it comes from the lode, is much richer and more valuable than an equal quantity of tin in the same state; the tin ore when prepared for sale, is at least seven times richer than that of copper*
>
> (Henwood 1832, 146)

8.2 TIN DRESSING

The origins of the techniques for dressing tin are not known precisely but the principles have changed very little since first documented and possibly since the earliest discovery of the metal. As has been argued, streamworks were worked long before the lodes and one of the principles of working stream tin is that the cassiterite, with a specific gravity of between 6.5 and 7.1, was much more dense than gangue material of a similar mass, typically 2.5 to 2.8, and would therefore sink more rapidly in still water and be moved less freely by the current of running water (Chapter 4). These principles are the essential basis behind all processes and techniques of tin concentration.

Tinners who searched for stream tin benefited from the effects of the weathering process (Chapter 3), which had partly sorted the ore from the gangue before it came to rest in the tin ground, but tin mined directly from the lodes was disseminated among the gangue within the matrix and therefore needed crushing to reduce the cassiterite and the gangue to a similar mass before the process of refinement could begin.

8.2.1 The stamping mill

Stamping mills before 1750

The stamping mill as a means of crushing tin has origins in the medieval period; specific examples were first documented in Cornwall in 1402 and in Devon in 1504, though in both counties their probable introduction is likely to have been earlier (Gerrard 2000, 104). The first drawing of a stamping mill appears in the European context of *De Re Metallica* in 1556 (Hoover & Hoover 1950, 314) but it was the anonymous writer of 1671 that provided the first detailed account referring to the type of tin stamping or ‘knocking’ mills in use in Devon. These ‘early’ mills have been the subject of several detailed modern studies (Worth 1953; Greeves 1981; Gerrard 1989; 2000) and the excavation of a mill at Colliford in Cornwall has added much to our knowledge (Austin et al 1989, 5-251) of the physical characteristics of these buildings; their contents are fairly well understood for the period before 1700.

In these early mills the stamps were heavy, vertical baulks of timber, shod with iron (stamp heads) and supported by a frame in which they could reciprocate freely; there was usually two or three stamps per mill, although Carew reports six on occasion (Carew 1601, D4,11). Ray however, writing in 1674 claims that 'The stamps are only two at one place' (Ray 1674, 121). Pegs protruding from each of the stamps engaged with tappets fixed into a horizontal rotating shaft powered by a waterwheel. As the shaft turned the stamps were raised to a certain height by the tappets then released in a set sequence, falling onto the tin ore contained within a timber box or coffer with a flat stone base. On the front of the coffer was a perforated iron grate through which the crushed tin, which was suspended in water, could pass into shallow settling pits when reduced to the required size. The basic principle described here changed scarcely at all in the period between Agricola's depiction in 1556, and the 1930s when the last set of water-powered tin stamps ceased work on Dartmoor (Greeves 1986, 45). The main developments were that of scale as the number of stamps increased with bigger waterwheels, and refinements to secondary elements of the machinery.

According to Gerrard 223 stamping mills were built in Devon and Cornwall in the period before 1700 known from documentary and archaeological evidence. Of these the majority of surviving structures are in Devon and the great majority of documented sites are of 17th century date (Gerrard, 2000, 107). Although stamping mills were developed to crush tin in western Britain, they were also used at copper and silver mines, probably from the earliest days of mining for those ores. Kalmeter (Brooke 2001, 47) mentions stamping ore at certain copper mines including Ausewell in 1724, and most of the succeeding 18th century writers' descriptions of copper dressing mention the use of stamps including Angerstein 1753-5 (Berg & Berg 2001, 106); Borlase (1758, 203) and Pryce (1778, 234).

The 'early' stamping mills that survive on Dartmoor were contained within small rectangular buildings constructed from stone. An overshot waterwheel was housed in an external stone wheelpit, with the drive shaft passing through an opening in the wall to power the stamps on the interior. Variations of this basic layout may be seen at Black Tor Falls, Week Ford (Newman 1993, 185-97), Mill Corner, Broad Falls and many other recorded examples (*vide* Gerrard 2000, Fig 56). The main diagnostic artefacts associated with 'early' stamping mills are the mortarstones. These are boulders which formed the base of the coffer, having one or more flat faces with worn elliptical hollows, arranged in pairs or threes, onto which the stamps crushed the tin. They were discarded when too worn and are often numerous at these sites such as Upper Merrivale where 24 have been found (Passmore 1998, 10-11). These items are never associated with later mills which probably used a rammed stone as a base for the stamps (Earl 1968, 77).

Stamping mills after 1750

The reason for, or date of, a departure from this layout is not known but by the 1750s the building to contain the stamps was not present in Borlase's (1758) illustration (Fig 8.1), which depicts a change of

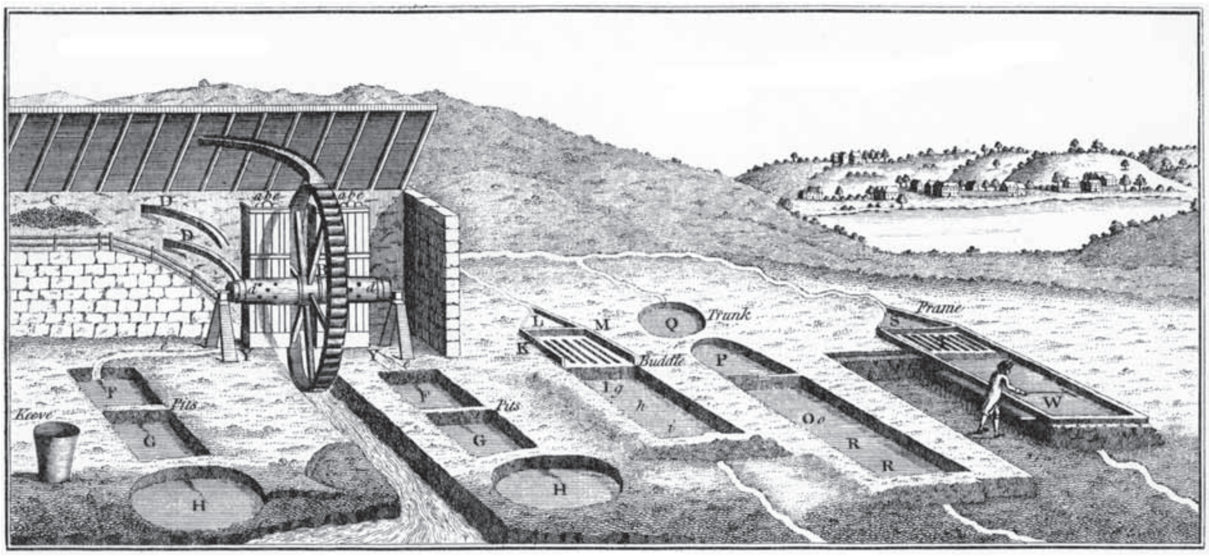


Fig 8.1 Engraving of a stamping mill and dressing floor from William Pryce's Mineralogia Cornubiensis of 1778.

layout to a type that would become standard and remain current until the 20th century. The essential layout for this more developed stamping mill, of which over 70 have been recorded on Dartmoor (Table 8.1), was a level terrace cut into the hillslope with a stone revetment built to retain the slope, often with short return walls at one or both ends (Fig 8.2). The wheelpits were sunk at right angles against or cut into the revetment, projecting into the levelled area. They were sited either at one end or centrally on the terrace, depending on the configuration of the stamps, which could be mounted on one or both sides of the wheel. Aligned with the waterwheel and further up the slope, a leat embankment was raised to the correct height to deliver water to the top of an overshot or pitchback (Chapter 9) wheel via a wooden launder. The tin ore was fed wet into a coffer, in the same way as the earlier mills, and once crushed by the stamps the product, known as 'pulp', passed through the perforated grate into rectangular settling pits. Placed along the remaining areas of the terrace was a series of additional pits used in the concentrating processes known as 'buddles'. The term for the area containing the settling pits and buddles is the dressing floor. In Borlase's illustration the stamps and dressing floors are protected from the weather by a roof, though the front of the working area remains open.

Slightly less developed is the 'stamping mill and buddles' shown in Angerstein's illustration of only one year previous to that of Borlase (Berg & Berg 2001, 95), which has a primitive looking water wheel powering two stamps on one side of the wheel with no sign of a building or wheelpit (Fig 8.3). It is uncertain whether Angerstein deliberately omitted any associated structure for clarity, or whether the example he sketched was in the open air. These two more or less contemporary illustrations show a contrasting level of sophistication. An explanation for this may be that the Cornish writer, Borlase, wished to project a modern technologically advanced industry while the visitor to Cornwall, Angerstein, simply reported what he observed.

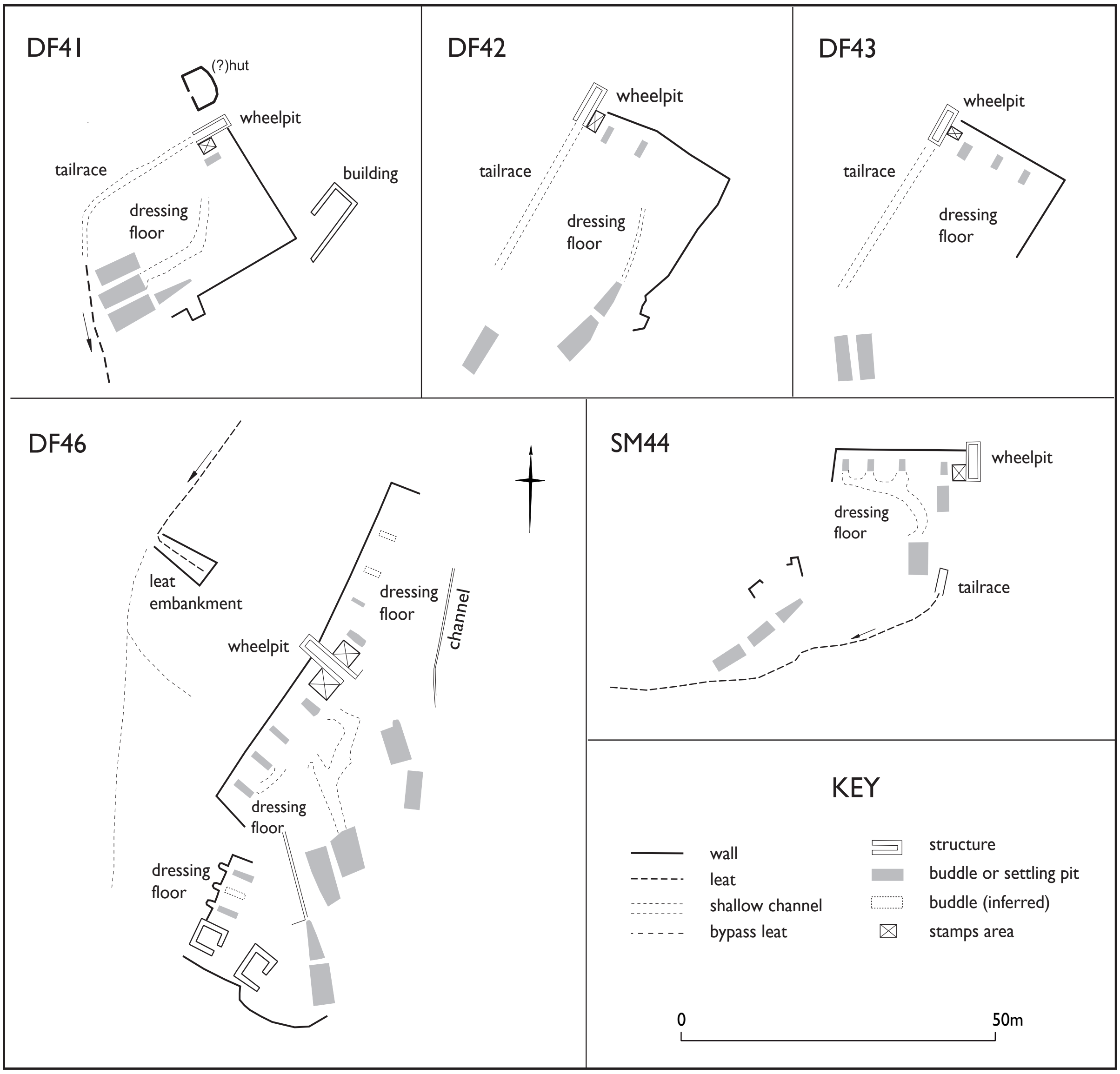


Fig 8.2 Simplified plans of stamping mills and dressing floors at Eyelsbarrow Mine, based on large scale surveys. Showing layout of single (DF41-44) and double (DF46) mills, positions of wheelpits, launders, settling pits, buddles and tailings pits.

8.2.2 The Dartmoor stamping mills - general

Previous writers have not examined the transition of stamping mill design. Gerrard discussed the early mill type in detail, but uses the arbitrary cut-off date of 1700 for his study; although citing documentation for stamping mills in the 1690s in Cornwall, he suggested no indication as to type except that mills with three heads of stamps were most common at that time (Gerrard 2000). Greeves, who focussed specifically on Dartmoor, divided stamping mills into pre 1750 (Greeves 1991) and post 1750 (Greeves 1997) but was unable to offer specific examples for the period leading up to or immediately after 1750. He suggested that the earlier mills were associated with a period of prosperity between 1450 and 1650, with some possibly as late as 1700 (Greeves 1991, 18-20), while the later type, after 1750, should similarly be seen in the context of a revival of tin in Devon from the late 18th century into the 20th century (Greeves 1997, 6-8). This leaves a notable void in the evidence, particularly in the field, between 1650 and the late 18th century, during which period tin is known to have been worked sporadically, but there is

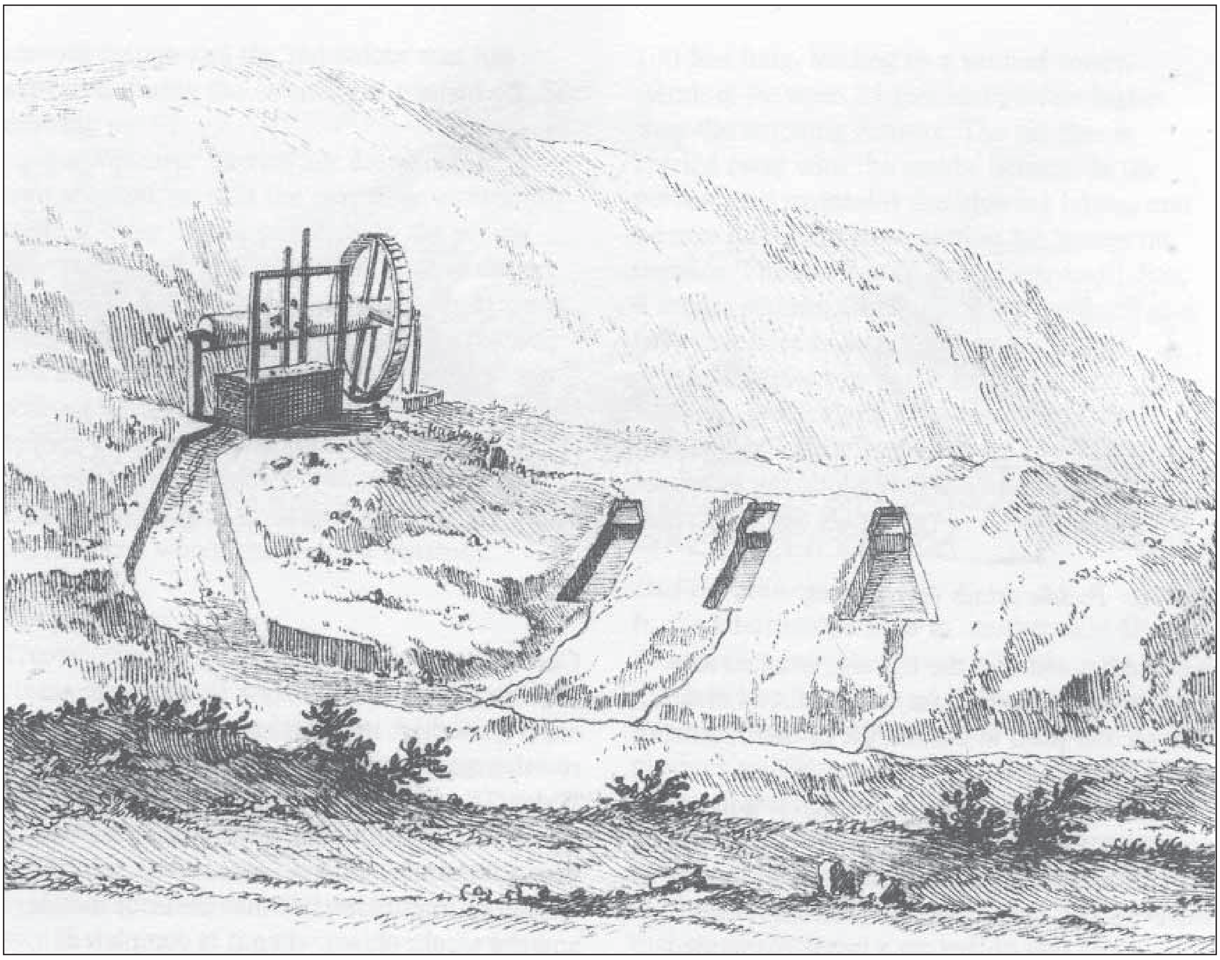


Fig 8.3 Sketch of stamping mill and buddles in Cornwall from Angerstein's Illustrated Travel Diary, 1753-1755 (Berg & Berg 2001)

a problem of providing securely dateable field remains which could establish the earliest use of this type. The vicissitudes in tin production would certainly have had a profound effect on the momentum of transition, but also on the quantity of data at our disposal. Following the English Civil War (1642-48), tin production in Devon fell to an all time low, and although reviving briefly in the early 1700s, the industry was almost flat-lining again by the 1730s (Table 4.1). This is precisely the period that the suggested transition would have taken place but the Devon tin industry was so inactive during this period that the volume of surviving documentation is commensurately low, hence documented tin stamping mills in the period between 1650 and 1750, for which field evidence may also be identified have not come to light. As Greeves' work has implied, some of the earlier class of mills could have survived at work into the start of the 18th century (Greeves 1991, 19). Mills at Week Ford (Newman 1995, 185-97), Mill Corner (NGR SX 6032 6722), and Black Tor Falls (NGR SX 5748 7164) are all in a sufficiently well-preserved and upstanding condition to be considered of that date, but documentation or excavated evidence to support this suggestion is lacking. It is indeed one possible explanation that during a period of impoverishment for the Devon tin industry, archaic technology might have remained in use; the low productivity of the Devon tin industry in the 18th century may have resulted in little 'new' investment in improving such machinery.

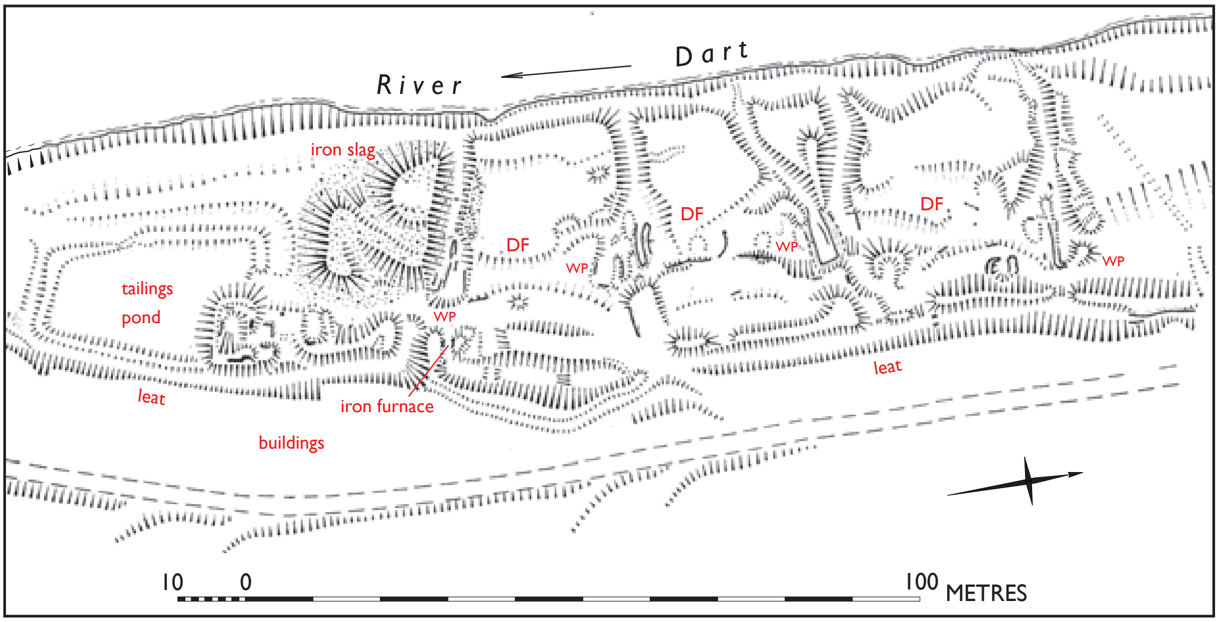


Fig 8.4 Earthwork plan showing eroded earthworks and fragmentary structural remains of stamping mills and dressing floors at Ausewell mines. This is a complicated site which also has evidence of blast-furnace and bloomery iron smelting of early 17th century date, but it is believed the copper (or tin) dressing floor features date from a phase of mid-18th century copper exploitation in the locality.

The illustration published by Borlase and Pryce was of a Cornish stamping mill at a time in the 1750s when the tin industry in Devon had declined to a state of near stagnation. Although there is no evidence to suggest that the same system was not adopted in Devon, as yet, evidence for the use of this type before the end of the 18th century is unknown. No mills of this developed layout are specifically documented for the first half of the 18th century, although it is known that stamps are recorded as working at several mines in that period. Kalmeter (Brooke 2001, 12, 46) for example mentions stamps working at the Black Down mines and Ausewell Mine in 1724. Ironically neither of these are tin mines; the former was a lead mine and the latter a copper mine. Ausewell offers the most likely location for archaeological remains of an early 18th-century stamping mill (Fig 8.4). Kalmeter's exact words when describing this site were, according to Brooke's translation 'At the foot of the hill and close to the river, *where the stamps now are….*' (Brooke 2001, 47).

Ausewell is a complicated industrial site, but a detailed survey in 1998 (Newman 1998) revealed the remains of four probable stamping mills in the vicinity of an iron blast furnace as described. But even these candidates have to be accepted with caution because, in 1791, on a lease for the mine it is stated that the lessee, one Christopher Gullett, had liberty and licence for:

> *..building and erecting the Stamping Mill and Mills in and upon the same usual Place and Places as have been done heretofore*
>
> (Brown 1997, 4)

Which implies that if Gullett did develop the mine, any older stamping mills may have been replaced, or at least upgraded, substantially altering any field remains. Stamping mills mentioned at Whiddon mine in Ashburton (CCRO DBC 1/17/2) in 1757 could potentially be very important to this study but so far fieldwork has not been possible at this site.

8.2.3 Stamping Mills Field evidence (Table 8.1)

Seventy-seven water-powered stamping mills of the more developed layout have been recorded in the study area at 52 mines; others may exist at sites which it has not been possible to visit in the course of fieldwork. Also, a small number of documented mills have either been destroyed or their whereabouts has not yet been established. Several mines have more than one stamping mill, with associated dressing floors; Bachelor's Hall (DF 64 & 66), Keaglesborough (DF 23 & 24) and Haytor Consols (DF 56 & 57) all have two mills but they are most numerous at Eylesbarrow which has six (DF 40-6).

Dating stamping mill field evidence currently relies entirely on documentation. In some cases therefore only isolated operational dates can be known with precision, and for some undocumented examples, no date of any type is available other than assumed or relative. For some however, absolute dates for installation are available, such as the six at Eylesbarrow Mine for which a combination of documentation and field evidence has combined to allow a chronology to be established with confidence (Newman 1999, 126-39).

Waterwheel pits

The waterwheels, which provided the power for the stamps were accommodated in wheelpits sunk into the ground and lined with stone. The size, where they can be measured, varies between the largest example at New Vitifer of 18.5m long, which housed a wheel of 60ft diameter (18.4m), and the smallest which were about 4.5 – 5m with wheels of approximately 15ft –16ft (4.5 – 4.8m). The width of the structures is between 3.7m at Golden Dagger and 0.8m at Wheal Chance. Waterwheels of largest proportions are always of later date.

Very few wheelpits survive intact, especially on the open moor where they were considered a danger to livestock and backfilled upon abandonment, but East Hughes Mine is one exception, where an overgrown but intact stamps wheelpit survives (DF14). A small number of examples in the private lands and woodland sites around the edge of the moor have also survived without demolition. These include Little Gem (DF36), Atlas (DF5), West Beam (DF77), Brimpts (DF55) and Kit (DF63, Fig 8.5). A second group comprises those wheelpits that have been backfilled, fully or partly, usually with stone and soil, but leaving the outline of the masonry lining visible; Wheal Mary Emma (DF50), Keaglesborough (DF23;24, Fig 8.6), Gobbet (DF22, Fig 8.7), Haytor (DF56;57), Rattlebrook (DF49), Wheal Frederick (DF51, Fig 8.16), Whiteworks (DF28;60;65) all fall within this group. Finally, several wheelpits have either been totally obscured by demolition, or have become overwhelmed by turf and survive only as

Fig 8.5 An intact stamps wheelpit at Kit Mine.

an earthwork with no masonry visible *in situ*. East Vitifer (DF38), Beardown (DF32), Kingsett (DF24), Wheal Caroline (DF12), Wheal Fortune (middle) (DF27), Huntingdon (DF29) are all visible only as earthwork hollows although in some cases, if archaeologically excavated, masonry of the wheelpits would certainly be revealed. Although the wheelpits were sunk into the ground the upper sections of the walls were frequently upstanding, especially where the pit was cut into a slope and the upper surface of the wall to support the axle needed to be level; in this case the lower end would be raised above ground to be level with the back end. The stone from these raised sections was usually the first material to be utilized for backfilling the pits and rarely remain *in situ*, though survivors are known at Caroline Wheal Prosper (DF15) and Great Wheal Eleanor (DF35; Fig 9.3).

Where the wheelpit was sunken substantially into the ground, the water, after passing over the wheel, left the chamber of the wheelpit through an underground tailrace. These survive at Caroline Wheal Prosper (DF15) and Lady Bertha (DF18) where the arched exit lobbies are visible inside the wheelpits at the lower end, and Wheal Mary Emma (DF 50) where the outflow can be traced in the river bank, but in the majority of cases the exit lobby has been obscured by the backfill. At several sites the lower end of the wheelpit remains open, having no end wall, which suggests the wheel was raised on its axle by a timber frame, and only a shallow masonry-lined channel was needed to accommodate the water. Examples are Keaglesborough 1 & 2 (DF23;24), Wheal Chance (DF11), and all six of the Eylesbarrow mills all of which date to the earlier part of the 19th century (DF41-46). These may be actual examples of what the Borlase engraving shows, with the axle raised some distance above the ground on sturdy timber supports, while the wheelpit is relatively shallow with an open lower end (Fig 8.8).

Stamps area

Set on one or both sides of the wheelpit were the stamps. In Borlase's engraving of 1758 three heads

TABLE 8.1 Stamping Mills and Dressing Floors

Name of Mine	A	B	C	D	NGR (SX)	Date	E	Reference	F	G	H	J	K	L	M	N	P	Q	Leats
Anderton	95	74	0	-	4880 7233	1845	OD	BI, Tavistock	-	-	-	-	-						-
Atlas	3	5	1	n/k	7810 7652	1889-1914	OD	OS 1st-2nd ed	S	-	-	S	S	✓		✓		G	✓
Ausewell	6	1	3	n/k	7269 7120	18th c	E	not recorded	S	5	1	S	S	✓	✓			F	L4
Ausewell	6	2	3	n/k	7269 7123	18th c	E	not recorded	S	5	0.9	S	S					F	L4
Ausewell	6	3	3	n/k	7269 7125	18th c	E	not recorded	S	8	2	S	S					F	L4
Ausewell	6	4	3	n/k	7270 7129	18th c	E	not recorded	S	6	1	S	S	✓				F	L4
Bachelor's Hall (Bullpark)	8	76	1	n/k	6015 7344	early 19th c	E	not recorded	PS	4.2	2.3	S	S					P	✓
Bachelor's Hall (lower)	8	64	3	n/k	5986 7341	1800-1845	E	not recorded	E	0	0	E	D					F	✓
Bachelor's Hall (riverside)	8	70	1	n/k	6016 7345	1790s	OD	Hamilton Jenkin 1974, 94	E	4.2	2.3	E	S					P	✓
Bachelor's Hall (upper)	8	66	3	n/k	5982 7342	1800-1845	E	not recorded	E	0	0	E	D					F	✓
Bal	10	33	2	n/k	5690 6931	1800	E	not recorded	S	6.8	1.7	S	S					F	✓
Beam, West	98	77	1	n/k	7652 7358	1836-47	ID	DRO 1164B/11/8	S	13	1.8	S	S		✓			G	✓
Beardown	11	32	3	n/k	5974 7626	1801	ID	Sherbourne & Yeovil Mercury, 09.02.1801	E	5	0	E	S					P	L14
Bertha, Lady	71	18	1	RB	4712 6891	1886-1906	ID	not present on 1886 OS 25"	S	10.8	1.5	S	S	✓		✓	6	G	L12
Birch Tor and Vitifer	12	16	2	n/k	6819 8091	1845-58	OD	MJ 23.01.1858		-	-	S	n/k		✓	✓			L6
Birch Tor and Vitifer	12	17	2	n/k	6833 8072	1903	ID	Greeves 1986	E	-	-	E	S			✓		P	L6
Birch Tor, East (lower)	24	62	0	n/k	6946 7999	1836-1852	OD	Broughton 1968-9; BI (North Bovey)	E	-	-	E	S						L6
Birch Tor, East (upper)	24	61	3	P	6944 8065	1836-1852	OD	Broughton 1968-9; BI (North Bovey)	S	6.5	0.95	S	S		✓				L6
Brimpts (lower)	15	73	1	n/k	6701 7384	1798	ID	Bird & Hirst 1996	-	0	0	S	S					P	-
Brimpts (North)	15	54	1	P	6530 7478	1853	ID	Bird & Hirst 1996	S	7.7	1.5	S	S		✓			G	L22
Brimpts (Plantation)	15	55	1	P	6658 7393	1850	ID	Bird & Hirst 1996	S	8.8	1.4	E	S		✓			G	L22
Caroline, Wheal	79	12	2	n/k	6663 8082	1826	OD	DRO 3665Z	E	0	1.5	E	S					P	L6
Chance, Wheal	20	11	3	P	5951 7002	1806	ID	DRO 1311M/deeds/4/6	S	6.5	0.8	S	S	✓	✓			F	✓
Combeshead	102	68	1	n/k	5850 6838	1830	OD	Greeves 1969	S	10	1.1	E	S	✓	✓			F	✓
Cumpston, Wheal	22	52	0	P	6727 7233	1840 pre-	OD	Greeves 1978	S	6.2	1.2	S	S		✓			G	✓
Devon United	106	75	1	RB	5121 7857	late 19th c	E	marked on 1905 OS 25" but not on 1884	S	0	0	S	S	✓		✓	4	G	L24
Dorothy, Wheal	78	6	1	n/k	6656 6647	n/k	-		E	5	2	S	S		✓			F	✓
East Hughes	39	14	3	P	5929 6995	1800-1830	E	not recorded	S	8	1.3	E	S	✓	✓			G	✓
East Lady Bertha	80	31	1	n/k	4780 6903	1856-61	OD	MJ 18.10.1856; MJ 13.07.1861	-	0	0	E	n/k			✓	2	P	-
Eleanor, Gt Wheal	25	35	1	n/k	7351 8342	1876	ID	EFP 23.08.1876	S	12.8	2	S	S	✓			3	P	-
Eylesbarrow 1	1	41	3	P	5944 6797	1814	ID	WDRO 874/50/2	S	6	0.9	E	S	✓	✓			G	L25
Eylesbarrow 2	1	42	3	P	5939 6785	1814	ID	WDRO 874/50/2	S	6.1	1.1	E	S		✓			G	L25
Eylesbarrow 3	1	43	3	P	5934 6776	1814	ID	WDRO 874/50/2	S	5.5	1	E	S	✓	✓			G	L25
Eylesbarrow 4	1	44	3	P	5929 6770	1804	ID	EFP 08.11.1804	S	5.7	1	S	S	✓	✓			G	L26
Eylesbarrow 5	1	45	3	P	5916 6763	1822	ID	Cook et al 1974	S	6.8	1	E	S		✓			F	L26
Eylesbarrow 6	1	46	3	P	5915 6747	1806	ID	EFP 08.11.1804	S	8.8	1.1	S	D		✓			G	L26
Fortune, Wheal (lower)	29	26	3	n/k	5520 7529	1806	OD	Greeves 1976, 3-5	S	-	-	S	S		✓			P	✓
Fortune, Wheal (middle)	29	27	3	n/k	5493 7538	1806	OD	Greeves 1976, 3-5	E	6	2.7	E	S		✓			F	L9
Fortune, Wheal (upper)	29	25	3	n/k	5495 7567	1806 - c1860	OD	Greeves 1976, 3-5	S	5.5	0.8	S	S					F	L9
Furzehill Wood	32	59	1	n/k	5159 6915	1860-76	OD	BI (Buck Mon)	D	-	-	E	n/k			✓	2	P	L7
Gem, Little	74	36	1	n/k	4945 7057	after 1850	E		S	6.5	2.3	S	S	✓		✓	3	E	✓

TABLE 8.1 Stamping Mills and Dressing Floors (cont)

Name of Mine	A	B	C	*D*	NGR (SX)	Date	E	Reference	F	G	H	J	K	L	M	N	P	Q	Leats
Gobbett	33	22	1	*S*	6465 7277	1831-2	ID	Greeves 2006	E	14	1.8	E	S	✓		✓	2	F	✓
Golden Dagger (1)	34	20	0	*n/k*	6837 8024	n/k				5	1.7	-	S						L6
Golden Dagger (2)	34	19	2	*n/k*	6834 8012	1906-1914	OD	absent OS 1906; Richardson 1992		7.5	3.4	E	S	✓				G	L6
Golden Dagger (3)	34	72	1	*S*	6846 8005	1809	OD	Greeves 1986; OS 1809	S	13	1.5	-	S						L6
Golden Dagger (Walla Brook)	34	71	3	*n/k*	6729 7991	1800-1830	E	Not recorded	S	6	1.1	S	S		✓			G	L6
Great Week	88	39	0	*n/k*	7157 8743	1887	ID	MJ 06.08.1887	D	-	-	-	n/k					D	?
Haytor Consols (Crownley)	9	56	2	*RB*	7667 7587	1853	ID	MJ 20.08.1853; BI, Ilsington	S	9.8	1.5	S	S			✓	5	G	-
Haytor Consols (Sig)	9	57	2	*P*	7619 7531	1853	ID	MJ 20.08.1853; BI, Ilsington	E	10.3	1.7	S	S	✓				F	-
Hexworthy (Henroost)	35	7	3	*RB?*	6605 7108	1880s	OD	Burt et al 1984	S	15.5	2	S	D	✓	✓	✓	4	G	✓
Hexworthy (Hooten Wheals)	35	8	3	*RB?*	6567 7084	1905	ID	Greeves 1986	-	-	-	S	n/a	✓		✓	2	F	-
Holne Chase	37	9	3	*S*	7143 7100	1874	ID	BI, Holne	S	4.5	4.2	E	S	✓		✓		G	L5
Huntingdon	7	29	3	*P*	6677 6693	1859	ID	CRO STA/1/136/1	E	15.5	5.5	E	S	✓		✓	1	F	L 27
Katherine, Wheal	41	40	3	*P*	6075 6829	1808 pre-	E	Newman 1999	S	8.8	0.9	S	D	✓	✓			G	✓
Keaglesborough	42	23	3	*P*	5728 7009	1801	ID	DRO 924B/B2/1	S	6.2	0.9	S	D	✓	✓			F	L15; L16
Keaglesborough	42	24	3	*P*	5738 7011	1830	OD	Brown (nd)	S	9	2.2	S	D	✓	✓			G	L15, L16
Kingsett	45	34	2	*n/k*	5784 6972	early 19th c	E	not recorded	E	7.5	-	E	S	✓				P	-
Kit	99	63	1	*RB*	5627 6744	1900	ID	BI (Sheepstor)	S	7.1	1.2	E	S	✓		✓	3	E	-
Mary Emma, Wheal	49	50	3	*P*	5323 8515	1850	ID	MJ 12.01.1850	E	13.5	1.3	S	S			✓	1	F	L18
Nuns, East	51	47	1	*P*	6145 6999	1800-1830	E	Woods 1850	S	4.8	0.7	S	S	✓				F	✓
Prosper, Caroline Wheal	53	15	3	*n/k*	7013 6585	1854	ID	HJ 1981	S	9.1	5.5	S	S	✓	✓			G	L2
Prosper, Wheal	54	53	3	*n/k*	5737 7935	1848	OD	Greeves 1975, 6	PS	5	0.9	E	S		✓			P	✓
Rattlebrook	4	49	2	*n/k*	5589 8565	c.1845	E	Greeves 2003, 22-4	PS	5.4	1.3	S	S	✓	✓	✓	1	F	✓
Ringleshuttes	57	10	2	*n/k*	6785 7032	1854	ID	MJ 21.01.1854	PS	4	-	-	S		✓			P	-
Ringmoor	58	69	1	*n/k*	5679 6719	1809 pre-		Lysons 1822	E	5	-	E	S					P	-
Roborough Down North	64	37	1	*n/k*	5131 6856	1863	ID	BI, Buck Mon		-	-	E	n/k			✓	2	P	-
Sortridge Consols	93	58	1	*n/k*	5085 7075	1850s-	OD		D	-	-	-	n/k	✓		✓	3	F	L9
Steeperton	47	13	3	*n/k*	6143 8840	1877	ID	Greeves 1986	S	9.9	3	S	S			✓	1	G	✓
Virtuous Lady	81	30	1	*n/k*	4722 6969	early 19th c	E	not recorded	E	5	1.4	S	S					F	L12
Vitifer, East	63	38	2	*n/k*	7088 8236	1846	ID	MJ 16.05.1846	E	14	4	S	S			✓	2	G	✓
Vitifer, New	65	48	3	*S*	6789 8275	1870	ID	BI (Chagford)	S	18.5	8	S	S			✓	3	G	✓
Walkham United	73	21	1	*n/k*	4949 7050	n/k			S	9.2	3.3	S	D	✓	✓	✓	2	G	✓
Wheal Frederick	31	51	3	*n/k*	5458 8537	1853	OD	MJ 5.02.1853	S	7.6	1.3	S	S	✓		✓	2	E	✓
Whiteworks (eastern)	40	28	3	*P*	6144 7108	1808 pre-	ID	Greeves 1980	E	6	-	E	S		✓			P	L19
Whiteworks (lower)	40	60	3	*n/k*	6153 7078	1840 pre-	OD	DRO AMP R43C	E	-	-	E	S			✓	2	P	L20
Whiteworks (upper)	40	65	3	*n/k*	6131 7083	1869	ID	Greeves 2002	PS	9	-	E	S					F	L20
Yeoland Consols	67	67	0/1	*n/k*	5216 6635	n/k				-	-	-	n/k			✓		G	-

A = Site No
B = Dressing Floor No
C = Level of Survey
D = Settling pit type (S = strip; P = pit; RB = round buddle; n/k = not known)
E = Date status (OD = operational date; ID = installation date; E = estimated date)
F = Wheelpit status (E = earthwork; S = structure; PS = part structure; D = destroyed)
G = Length of wheelpit if known
H = Width of wheelpit if known

J = Dressing floor revetment (E = earthwork; S = structure)
K = Dressing floor type (S = single; D = double H = Width of wheelpit
L = Stamps area
M = Rectangular buddles
N = Round buddles
P = Number of round buddles
Q = General condition (D = destroyed; P = poor; F = fair; G = good; E = excellent)

of stamps are shown on either side of the wheel, six in total, driven directly from the wheel axle, which extends beyond the width of the wheel rims (Borlase 1758, Pl 19.3). Angerstein shows stamps on one side of the wheel only (Berg & Berg 2001, Fig 95) in his illustration; both systems were adopted widely, with field evidence of both surviving in abundance. In a description of progress at Eylesbarrow Mine in 1805, the layout with stamps either side is referred to as a 'double' mill (*EFP* 08.11.1804), while in 1818 both a 'double' stamping mill and a 'single' stamping mill were for sale at Whiteworks (Greeves 1980) and these terms are adopted here.

The number of stamps installed at individual mills increased as the technology developed and as larger waterwheels were introduced, capable of generating more power. The stamping mills that can be identified as of early 19th century date (Table 8.1) often have stamps areas defined by solid platforms with stone edges. All of the mills at Eylesbarrow have these (Fig 8.2), but also Gobbett, Wheal Chance,

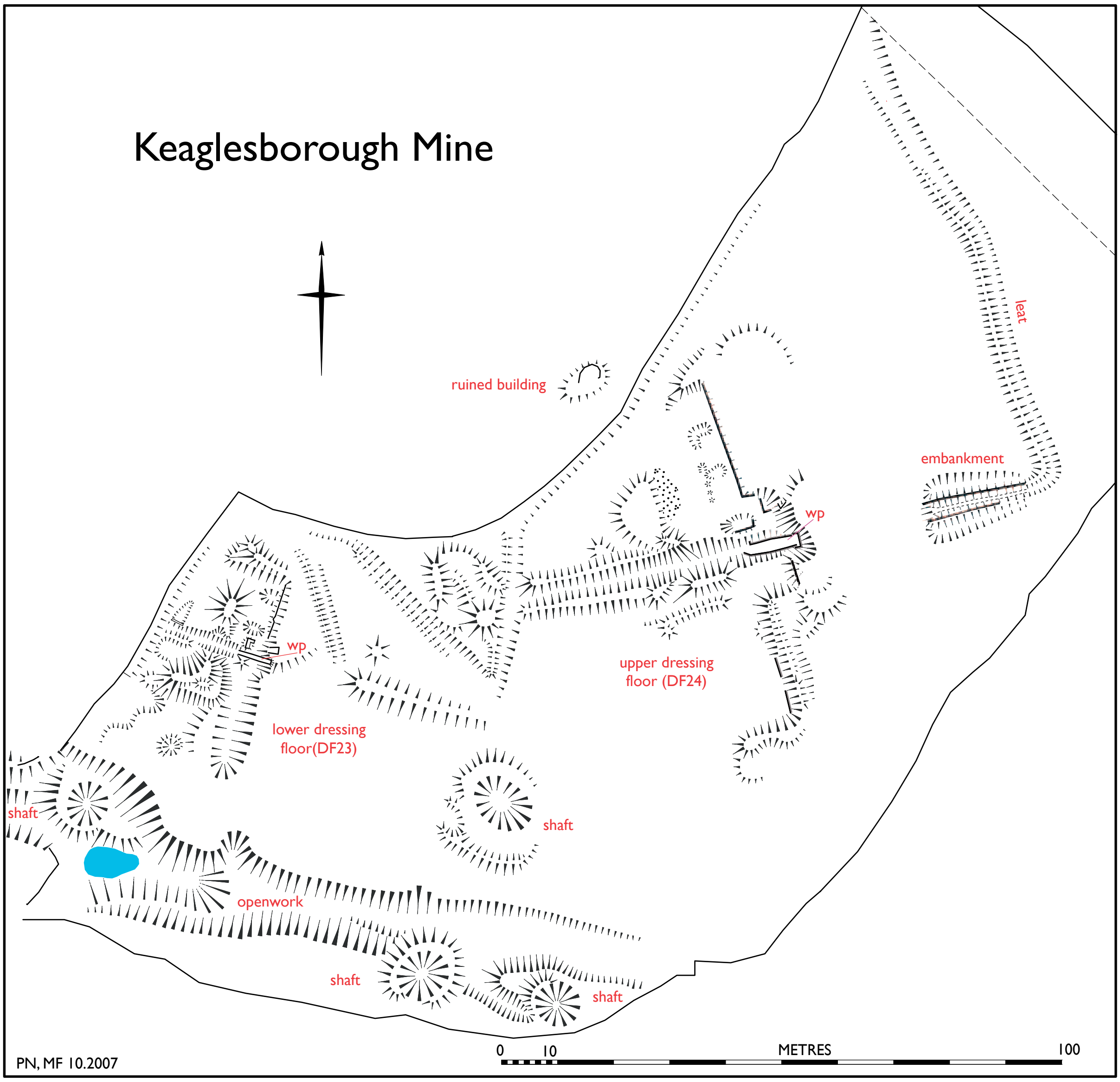


Fig 8.6 Earthwork plan of Keaglesborough tin mine. The mine had two dressing floors; the lower smaller example may be earlier. Also shows the upper section of the openwork which has been penetrated by later shafts.

Fig 8.7 A sunken stamps wheelpit at Gobbett mine which has been part demolished and backfilled.

Keaglesborough lower mill, Wheal Katherine (DF40) and Wheal Fortune. The largest of these is at the double mill at Eylesbarrow (DF6; Fig 8.8) which measures approximately 3m by 3m. These platforms are absent from many mills, especially those of later date which housed larger batteries of stamps. A photograph of 1889 shows Whiteworks upper mill, which was installed in 1869 (Greeves 1989, 2), with 16 'heads' of stamps. Similarly a photograph of the stamps at Atlas Mine (Greeves 2008, Fig 10), which was established after publication of the 1st edition OS 25" map of 1886/7 on which it is not depicted, shows 24 heads of stamps. At neither site was a platform of the type used at the earlier mills in evidence, which may have had space for four each side of the wheel.

Ore was fed into the back of the stamps via a 'pass' – a steeply inclined timber chute, which delivered the ore from a raised platform (Fig 8.9). These passes do not survive but the platform is visible as a flat-topped earthwork to the rear of the stamps area at Gobbett, Huntingdon, Brimpts (DF54), New Vitifer, Whiteworks (DF60). In the latter case the platform acted as a terminal for a tramway, delivering ore directly from the mine.

8.2.4 Dressing floors

The generic term 'dressing floor' refers to any working area at a mine where ore was concentrated or 'dressed', but where associated with a stamping mill it specifies the level areas adjacent to the wheelpit and stamps, which contained the further processes associated with stamping. In particular, the processes that involved settling and concentration of the ore in water were carried out in these areas.

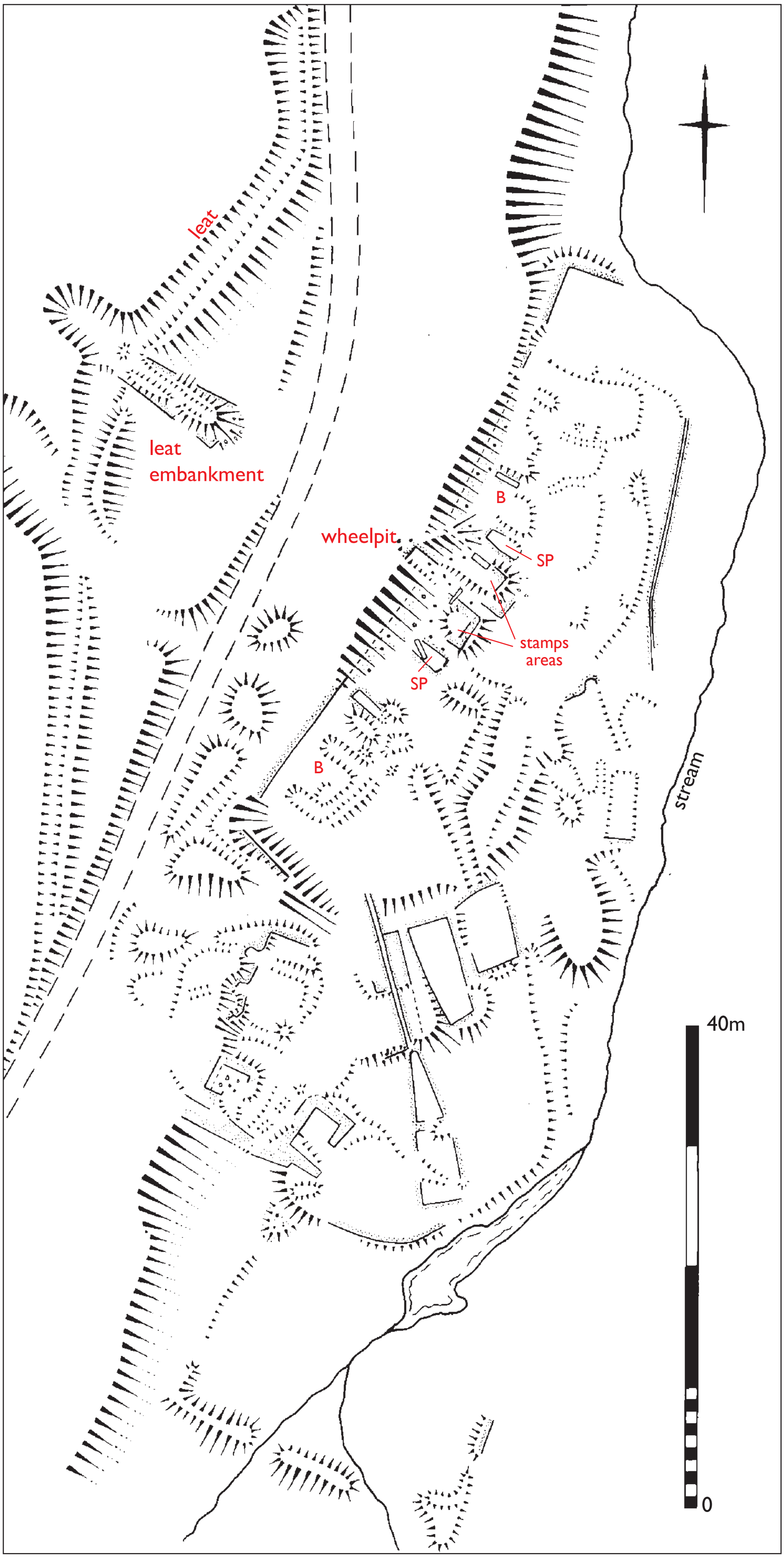


Fig 8.8 Large-scale earthwork plan of the double stamping mill and dressing floors at Eylesbarrow Mine. Highlighting features around the wheelpit and stamps area. The wheelpit has been backfilled. See Fig 8.3 for interpretation. SP = settling pit B = buddle area

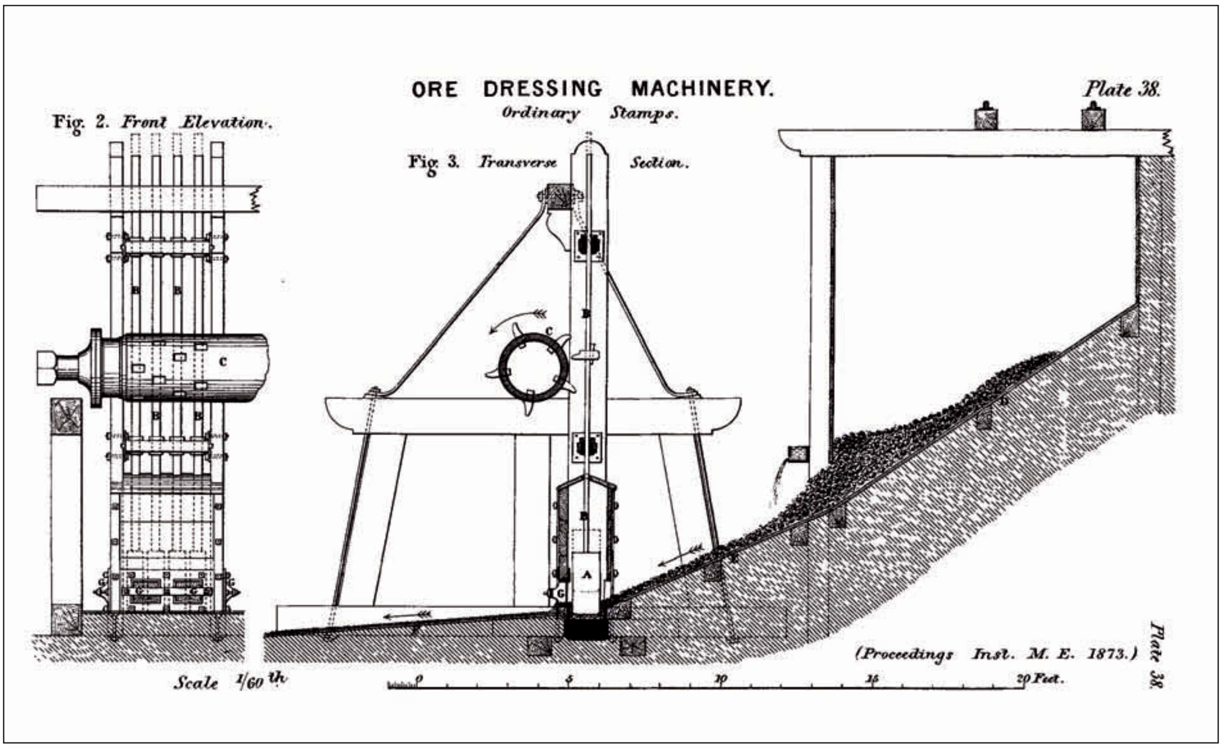


Fig 8.9 Front and side elevations of a stamping mill from Ferguson 1873. The main field evidence for this type of installation, apart from the wheelpit which is not shown, is the raised platform at the extreme right which supported the ore pass.

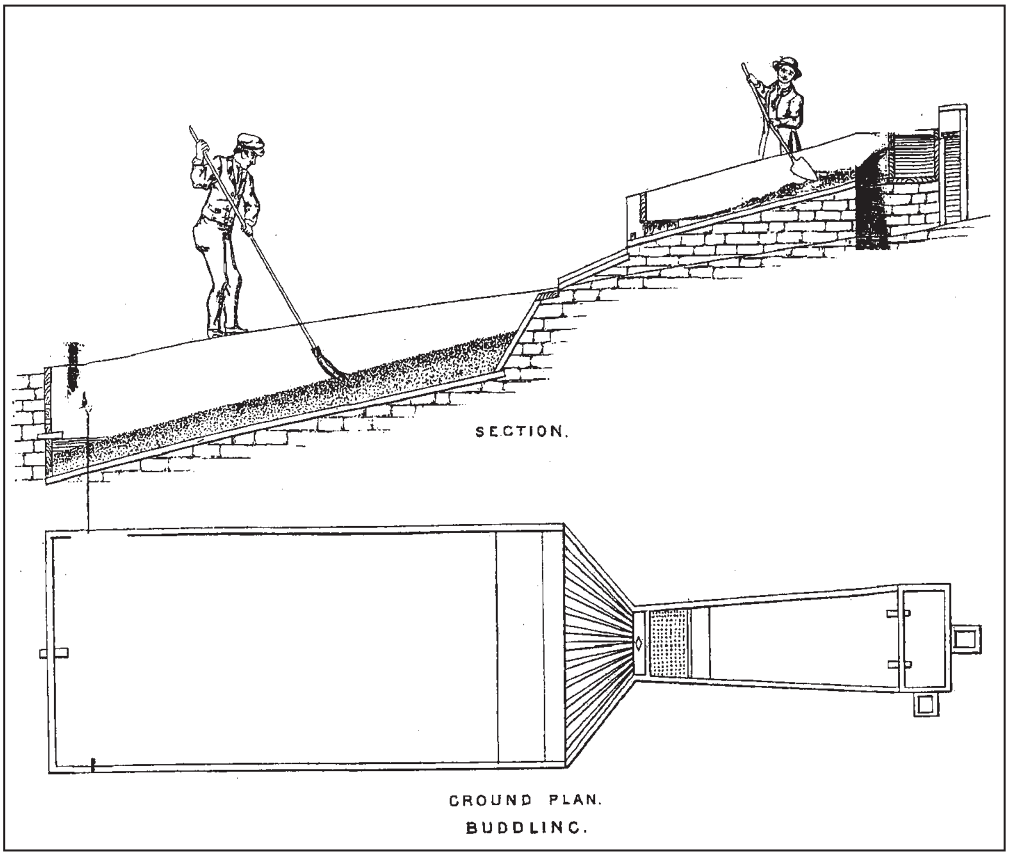


Fig 8.10 Drawing of a rectangular buddle from Henderson 1858, showing the timber components which do not survive as field evidence.

Settling pits and strips

Some of the most significant technical innovation in ore processing occurred at the dressing floors, where the methods of concentration was the main focus of improvement. Like the stamping mills, dressing processes are also well recorded over the centuries starting with Agricola, whose 1556 woodcut shows the water mixed with crushed tinstone (pulp) passing through the grate of the coffer into rectangular troughs set at slight gradients in front of the stamps, then into settling pits outside the building (Hoover & Hoover 1950, 314-15). The working principle of the settling pit was that the heavier tin would settle near the head of the trough ('heads') while the lighter waste ('tails') would come to rest nearer the lower end. Once full, and the water had drained away, the two grades could be separated for further processing.

In 1601 Carew describes something very similar whereby:

> *the stream, after it hath forsaken the mill, is made to fall by certayne degrees one somewhat distant from another; upon each of which, at every discent lyeth a green turf, three or foure foote square and one foot thick….*
>
> (Carew 1602, 12r)

In 1671 the trough in which the pulp collected was described as a '*Launder*':

> *(i.e. a trench cut into the floor, 8 foot long and 10 foot over) stopt at the other end with turf so that the water runs away, and the Ore sinks to the bottom..*
>
> (Anon 1671, 2108)

In 1758 Borlase describes this same device and depicts two coaxial rectangular pits, which he names the 'forepit' and 'middle pit', followed by a third circular pit referred to as the 'slimes pit' (Borlase 1758,

Fig 8.11 The substantial retaining wall and ore-dumping area at Crownley Parks dressing floors, part of Haytor Consols.

178). Slimes was a by-product of the stamping mill caused by particles of tin and waste dwelling too long in the coffer, being over stamped and becoming too finely crushed. It remained suspended in water longer than the larger particles and needed treating separately, thus the water as it overflowed from the middle pit, carried the slimes with it into the slimes pit.

In Henwood's description of 1832, little had changed, and the two main pits were described in very similar terms (Henwood 1832, 148). But by 1858 a different system had been introduced according to Henderson who describes and illustrates the ore after passing through the grates, being conveyed down an incline divided into strips. He comments that the former system of two pits:

> *have generally be superseded by strips which are wooden troughs, from 35 feet to 40ft in length, 18 inches wide, 15 inches deep, with a fall of about 1 foot…. There are usually three strips to each set of four stamps*
>
> (Henderson 1858, 195-220).

In 1873 Ferguson describes more or less the same apparatus but adds that at some mines strips were not used and that the stamped tin passed straight into round buddles placed just below the stamps (Ferguson 1873, 123). Palmer and Neaverson's study of West Bassett in Cornwall (1986, 64) indicated that of these two systems neither was universally adopted, both having their advocates in the 1880s.

Buddles

Buddles were the main apparatus for the concentration of tin ore and had probably been in use at least as long as the stamping mills themselves, being mentioned by Agricola and all the subsequent writers listed above. Early buddles consisted of an elongated rectangular pit or a trough, with an inclined floor. Crushed ore, which had received an initial sorting in the settling pits, was introduced to the upper end of the buddle in a stream of water that ran down the incline. Agricola's 1556 woodcut shows the buddles as timber troughs raised above the ground, which if adopted would have left little archaeological evidence other than residues, but by 1758 Borlase's illustrations show the buddles as rectangular pits sunk into the ground. Forming the bottom of the buddle was an inclined timber board. At the head of the buddle was a slightly more steeply inclined board, the 'jagging' board, onto which the partly dressed tin was placed into a gentle stream of water, which carried the tin into the buddle and, using the same principle as the settling pit, the heavier tin would sink near the head while the waste was washed to the tail. When full, the water was drained away and the product dug out and separated into three grades of purity, 'heads', 'middle heads' and 'tails', each of which underwent differing additional processes.

Apart from slightly differing dimensions all the technical accounts from Anon in 1671 to Henwood in 1832, describe rectangular buddles in this way but in 1858, Henderson describes them as 'the old-fashioned form of buddle, which is still frequently used…' (Henderson 1858) and goes on to described the circular version, known as the convex or centre-head buddle; this was a variation whereby the buddle pit is circular with a central cone and inclined surface radiating from the centre. (Fig 8.14). The tin stuff and water were released onto the central cone to flow outwards and become separated by the same settling principles as the previous processes discussed. Rotating sweeps or brushes agitated the mixture in the buddle to aid the separation. The latter was powered by small waterwheels located amidst the dressing floors, each wheel powering several buddles via line-shafts. These features are clear on photographs of Golden Dagger Mine (Greeves 1986, 51) and Lady Bertha (Hamilton Jenkin 1974, 74) whilst still operational in the early 20th century.

One account from the later 19th century claims that the precise date for round buddles coming into use was 1842 (Reyer 1894, 138-50) and clearly a transition in buddle technology was developing at tin mines between 1832 and 1858 at the time of Henderson's statement. By 1873 only the circular buddle in various forms was considered worth mentioning by Ferguson in his treatise; indeed, rectangular buddle were scoffed at as being far too labour intensive (Ferguson 1873, 138). By the late 1870s references were made to improved types of circular buddles, with a much larger central cone (Darlington 1878, 134). Concave circular buddles had also been introduced by the 1870s (*Idem*) whereby the incline sloped down towards the centre; these were notably absent from Henderson's article of 1858 and must have been a later innovation.

By 1894, buddles had become of secondary importance to those reporting on the cutting edge of dressing technology, such as Davies, who highlighted their disadvantages of continually having to be stopped and emptied, by comparison to the continuous feed type machinery which was coming on line at that time

Fig 8.12 Stone-lined rectangular buddles at Caroline Wheal Prosper.

(Davies 1894, 297). However, on Dartmoor it is known that circular buddles continued in use; at Golden Dagger Mine photographic evidence confirms they were still in work at around 1930 (Greeves 1986, 62).

8.2.5 Dressing floors field evidence

Dressing floors, when combined with a stamping mill are usually defined by a stone revetment as described above, delineating the back edge of the floor. In many cases these revetments survive *in situ*, as at Keaglesborough (DF24, Fig 8.6) where a robust 1m-high wall defines an area of approximately 62m long by 9m wide. Several of the Eylesbarrow dressing floors (DF41-46, Fig 8.2) survive in similar condition, as does that at Wheal Katherine (DF 40). The most impressive of these sites is the Haytor Consols (DF56) Crownley site, which has very robust revetment wall approximately 1.3m high on either side of the wheelpit and an upper terrace, also revetted, where ore was deposited from trams before being fed into the ore pass (Fig 8.11). At several dressing floors, however, the revetments have tumbled and survive only as a stony earthwork scarp, as at Wheal Fortune (DF27), Wheal Caroline (DF12) and the Bachelor's Hall floors (DF64;66).

Settling pits

As is to be expected, evidence for strips are found at dressing floors documented from about the 1860s, but settling pits were installed at a new dressing floor at Brimpts constructed as late as 1853 (Bird & Hirst 1996, 18)

Field evidence for the earlier system of rectangular pits and a slimes pit is relatively common among the recorded dressing floors, although not all conform precisely to the contemporary descriptions and layouts vary. The pits usually survive as rectangular, masonry-lined depressions, which are often sufficiently silted to be visible only as earthworks, although the stone linings may often be defined. Brimpts north mill (DF54) is a key exemplar, having two distinctly separate elongated pits of 3.3m by 1.7m and 7m by 2.1m sited just below the stamps area (see Bird and Hirst 1996, 45 for plan). At Keaglesborough upper mill (DF24, Fig 8.6), which may have been installed as late as 1830, there is one large pit of 5.8m by 2.5m by 0.6m deep, with masonry lining still visible and at the lower mill (DF23) of probable earlier date, the pit survives only as a silted earthwork. Although the dressing floor of this mill has had material dumped on it, the outline of a small slimes pit is visible on the bottom edge of the floor. The Keaglesborough mills have documentation dating them to between 1801 and the 1830s (NMR SX 57NE 199) but the Brimpts floors are more closely dateable to an installation date of 1852-3 (Bird & Hirst 1996, 18).

At Eylesbarrow Mine all six of the dressing floors (Fig 8.2) have remains of settling pits, which vary slightly from the text book description. In all cases these comprise pits, now silted, lined with slabs of stone of between 2.6 and 3m long with tapering head ends and sluice openings at the tail end. In each

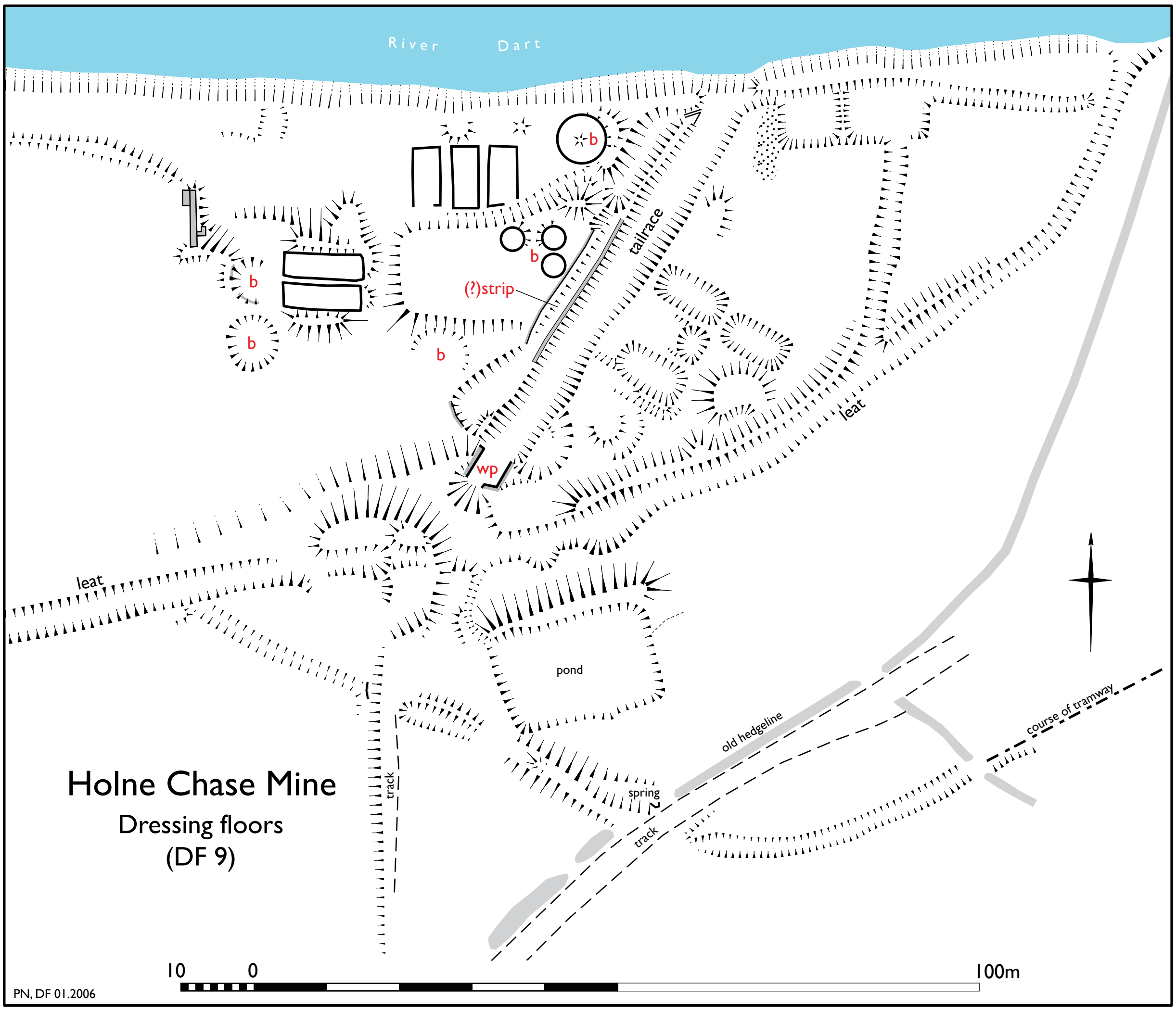


Fig 8.13 Earthwork plan of the dressing floors at Holne Chase Mine. The stamping mill layout is somewhat unconventional and there is some doubt as to the function of the rectangular features which may be later fish ponds. However, seven circular buddles survive as earthworks.

case they are positioned to one side of the stamps area. Only one of the floors has a secondary pit directly below, all the others have channels, in some cases covered or stone lined (Fig 8.12), leading into one, two or three larger rectangular pits at the edge of the floor. The construction of five of these mills was recorded between 1804 and 1814 (Newman 1999, 126).

Evidence for the later 'strip' form of settling pit is less easy to identify and was perhaps less common. In 1985 a tin stamping mill and dressing floor was partially excavated and surveyed before destruction at Wheal Prosper, Lanivet near Bodmin in Cornwall. One of the features revealed was the strips, incorrectly termed the slimes tank by the authors (Gerrard & Sharpe 1985, 200). This comprised an 8m-long gully with a concrete lining, with impressions in the concrete running lengthwise where the timber of the strips were positioned. Prior to excavation the feature had been visible as a definite negative earthwork. Similar evidence is rare on Dartmoor, only three sites so far recorded have presented such evidence, though as yet no concrete examples are known. At Holne Chase Mine (DF9; Fig 8.13) a 16m-long by

2.8m-wide channel, lined with masonry, is likely to represent the remains of strips and the probable 1870s date of the mine makes this very likely (Newman 2006). Another probable example may be seen at Gobbet Mine (DF22). The stamping mill was recorded in the early 1830s (Greeves 2006, 12-13) but the mine was also working in the 1860s – 70s. Just below the stone reinforced stamps platform a silted linear earthwork channel of approximately 5m long by 2.5m, representing the probable remains of the strips, leads down to two larger rectangular pits of 8.5m by 6.2m and 5m square to receive the slimes. Although the evidence is poor it is likely that New Vitifer mine (DF48, Fig 8.15), installed in 1870 (BI, Chagford), also used the strip system. A subtle negative earthwork of 10m long by up to 5m wide, on the north side of the wheelpit, below the stamps area represents all that remains of the feature.

Buddles

Earthwork evidence for rectangular buddles survives at 30 of the recorded dressing floors (Table 8.1) and as is to be expected, of those which can be dated, most are of the period prior to 1840. The majority survive only as silted and turf-covered approximately rectangular hollows of various depths, as at East Hughes (DF14), Wheal Fortune (DF27) and Brimpts (DF55) but some clearer examples exists at Eylesbarrow (DF44;46), Wheal Cumpston (DF52) and Wheal Katherine (DF40) which each have stone linings still visible along the edges of the buddles. The silting has caused many to lose their shape and definition, suggesting that they may have been lined with timber as an alternative to stone, which has since decomposed. Excavation of a sample of these features would be useful to establish details of construction and materials used.

Circular Buddles

The field evidence suggests that the circular buddle was widely adopted on Dartmoor from the approximate time of its inception at around the 1840s and although rectangular buddles continued in use at Eylesbarrow into the late 1840s (Newman 1999, 127) and were still being installed, notably at Brimpts in 1853 (Bird & Hirst 1996, 18), by that time the circular design had also been adopted at several mines.

A possible early documented use of circular buddles may be 1840 when the site of the lower stamping mill at Whiteworks (DF60) is depicted on a plan of the mine of that date (DRO AMP R43C). Although today overwhelmed by boggy vegetation, it is known that this dressing floor had circular buddles from its depiction on the 1st edition OS map of 1886 after abandonment and it is likely that these were part of the original 1840 installation. A more definite record of a circular buddle is mentioned in the Cost Book for Huntingdon Mine in 1859 (CRO STA/1/136/1). This single buddle (DF29) survives as a clear but turf-covered negative circular earthwork.

Typically a circular buddle will survive as a flat-bottomed hollow, often with evidence of a stone kerb lining the circumference. On early examples, such as that at Huntingdon, the interior details including

Fig 8.14 Circular buddles at Yeoland Consols(top), Kit(centre), Walkham and Poldice(bottom).

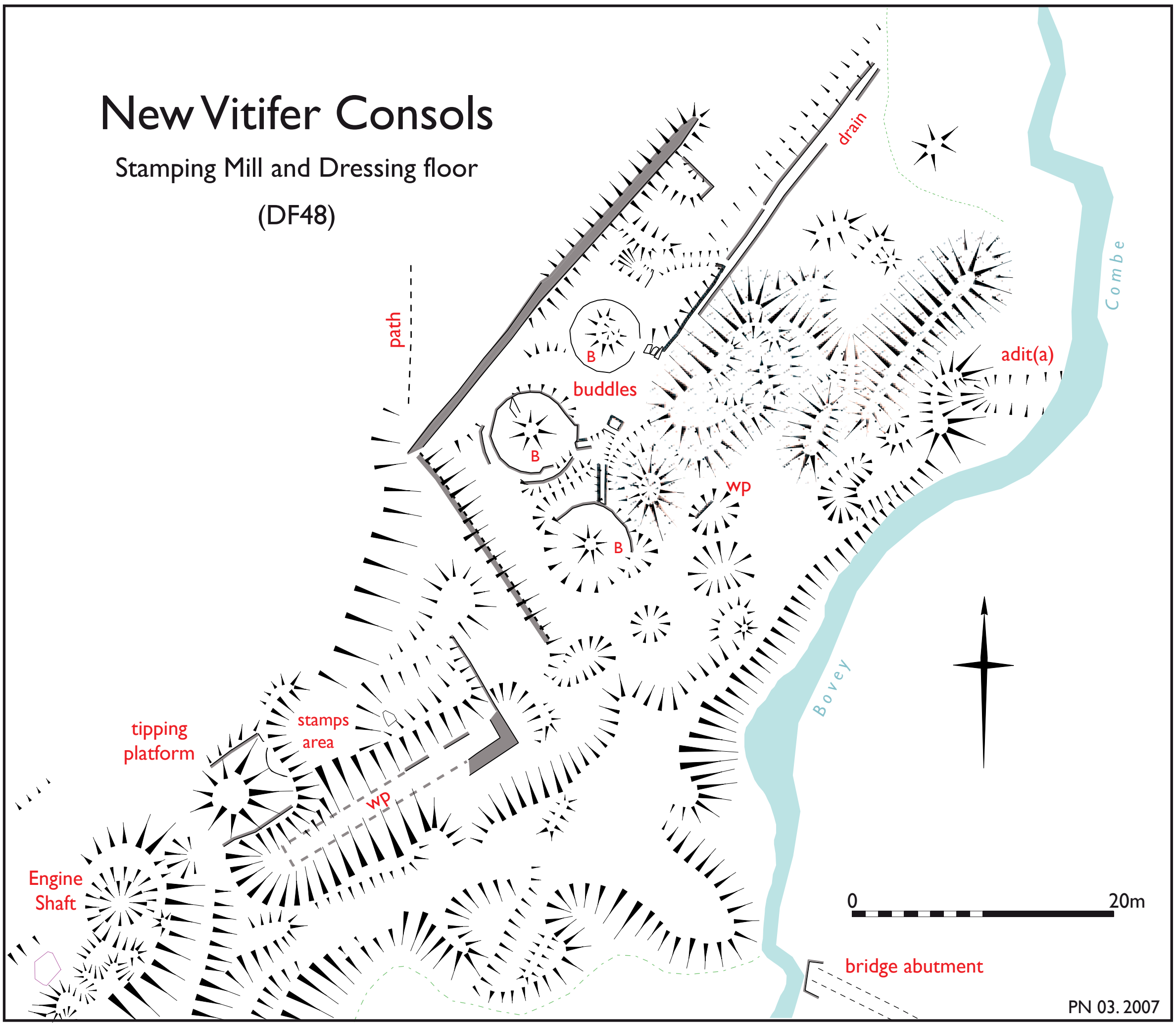


Fig 8.15 Earthwork plan of New Vitifer Mine dressing floors. The massive wheelpit, which accommodated a 60ft waterwheel to power pumps and a stamping mill, has been backfilled but the dressing floor survives with a stone revetment wall defining the floors and earthwork remains of three well-defined circular buddles. The large heap sited on the dressing floor is likely to be the material removed when the wheelpit was created

the dome would have been constructed from timber, hence the earthwork is all that survives. As the 19th century progressed it became more common for the domes to be made from stone and concrete, and they often survive *in situ* as a result (Fig 8.14). Timber remained in use however, as photographs of decaying timber buddles at the Golden Dagger mines last used in the 1920s demonstrate (Greeves 1986, 77).

In Cornwall, at large tin mines, it was not unusual for the dressing floors to contain 50 or more circular buddles. At Phoenix Mine on Bodmin Moor for example, where 61 were depicted on the OS map of the 1880s (Sharpe 1993, 150). At Dartmoor mines with more modest output the number was much smaller. At Lady Bertha Mine (DF18) there are six buddles surviving but often two or three is the norm as at New Vitifer (DF48; Fig 8.15), Wheal Frederick (DF51; Fig 8.16) and Hexworthy (DF7; Fig 8.17).

The use of the circular buddles was not restricted to tin mines and their presence at lead mines is known to have been widespread (Palmer & Neaverson 1989, 32). Examples have also been recorded at two silver-lead mines in the study area at Silverbrook near Ilsington and Wheal Betsy at Mary Tavy.

8.2.6 The over-capacity of stamping mills and dressing floors

The presence of stamping mills as part of the surface evidence of a tin mine, together with their attendant dressing floors and associated structures, would suggest that the managers of the mines in question built these installations through necessity to process large quantities of ore being raised from the mine. This was certainly the case at the large-scale and some small-scale productive mines, but it is notable that for a number of tin mines in the prospect and developed prospect category, the capacity to process the ore is many times greater than would have been required, judging by the evidence for underground development. Some clear examples survive: Holne Chase, which had a large capacity dressing floor and stamping mill (DF9) associated with a mine which was barely developed underground at all. Caroline Wheal Prosper had two dressing mills, though one was later destroyed, but had scarcely any development underground. New Vitifer, which was worked between 1867 and 1875 (BI, Chagford), has a 60ft wheelpit surviving with an extensive dressing floor (DF48), though evidence of underground development is also minimal. Great Wheal Eleanor, was in work between 1874 and 1881, where a 40ft waterwheel powering 16 heads of stamps was augmented by a steam-powered stamping mill with a further 16 stamps (DF35). This information is known from the auction details following closure of the mine in 1881 (BI, North Bovey). At that time it is also recorded that the maximum depth of Great Wheal Eleanor's shafts was only 20 fathoms, and the mine had sold only 10 tons of ore in 1879 and 3 tons in 1881 (IoM 1879, 514; 1881, 557). Claims by the management in newspaper reports of further small sales are not verified in the mineral statistics. At Haytor Consols are the remains of a particularly impressive stamping mill and a dressing floor (DF56; Fig 8.11), which it is recorded housed 32 heads of stamps when installed in 1851 and a second mill brought this number up to 48 (Hamilton Jenkin 1981, 133). Although 16 tons of tin was sold between 1853-5 (Collins 1912, 506) and 14 tons between 1863-5 (Burt et al 1984, 4) evidence of underground working at this mine is minimal, comprising a few short adits, shafts equipped with horse whims and, although one shaft has a moderate spoil heap, generally there is very little spoil associated with this mine; indeed nothing commensurate with this level of dressing capacity. Extensive dressing floors and remains of a large waterwheel pit also survive at East Vitifer Mine representing a period of activity after 1870 (BI, North Bovey) during which period minimal quantities of tin were sold, often little over one ton for a whole year (Burt et al 1984, 114)

Finally, Eylesbarrow Mine where five stamping mills are known to have been either operational or under

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Fig 8.16 (overleaf) Earthwork plan of the stamping mill and dressing floors at Wheal Frederick. Showing the leat, leat embankment, wheelpit and stamps area, dressing floors with two circular buddles. Ore was delivered to the rear of the stamps area along a tramway.

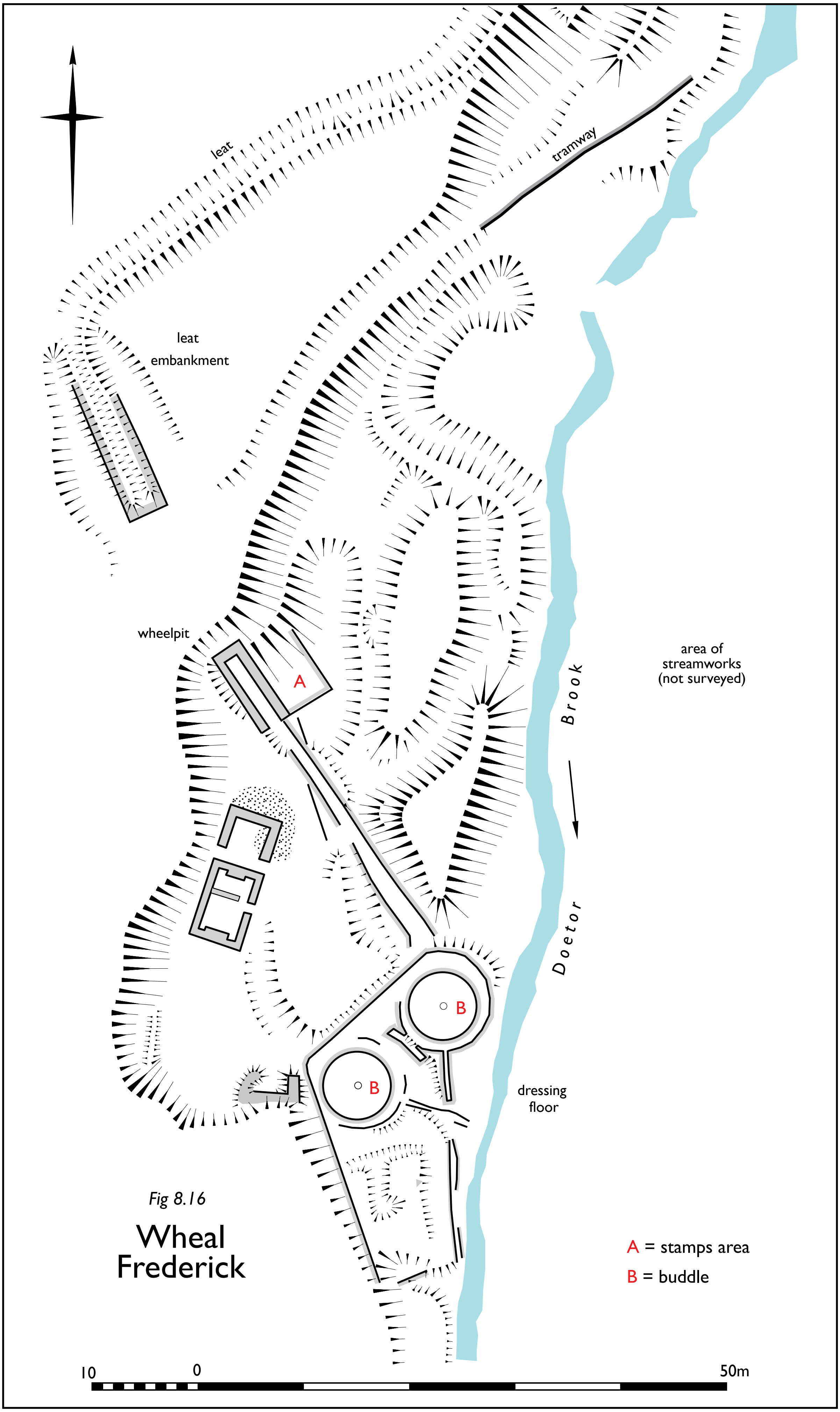

Fig 8.16

Wheal Frederick

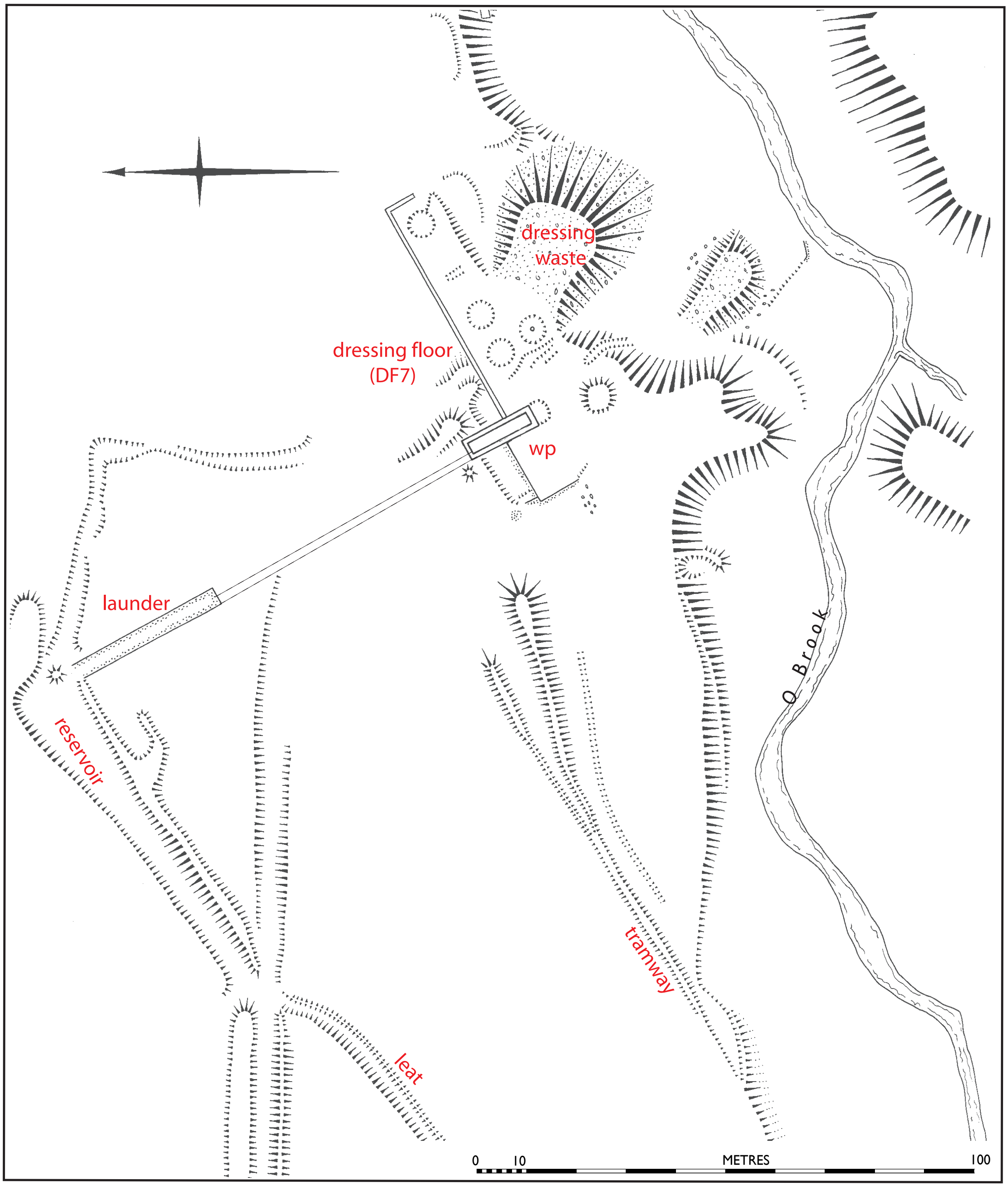

Fig 8.17 Earthwork plan of Henroost tin mine dressing floor, constructed in the 1880s. Ore was delivered in skips which ran along a tramway to the back of the stamps area. The stamps were powered by a waterwheel contained in a 10m-long wheelpit (WP13), driven by water stored in an earthwork reservoir up the slope. Tin was concentrated in a series of circular buddles and waste was tipped onto a large dump below the floors.

construction in 1814 and a sixth added in about 1822 (Newman 1999, 126). Although this mine was at times productive, particularly in the 1820s (Cooke et al 1974, appendix B), these five mills almost certainly represent dressing capacity far beyond likely output of ore from this mine. Although it has been suggested that this over capacity could have been employed to stamp the ore from neighbouring mines (Cook et al 1974, 190), this is unlikely given the problems of moving the ore from the mines in the surrounding valleys to these higher altitude dressing floors. Although it was essential to have some capacity to stamp ore following the development stage of a mine when production began, archaeological and documentary evidence confirms that many of these examples were installed long before the mines were even partly proven underground.

These cases all indicate either over-capacity or premature investment in unnecessary ore dressing machinery, which might be explained in a number of ways. Over-optimism or a genuine miscalculation as to the future prospects for the mine, based on a failure to grasp the limitations of Dartmoor's tin lodes, is one possibility although in a carefully budgeted and genuine enterprise this would be unlikely. Broughton (1971, 1-25), who cited the case of Haytor Consols in particular, citing much (unreferenced) supporting documentation, explained the situation as the result of reckless or inexperienced management and malpractice. Indeed this common scenario may often represent the material evidence of 'bal selling' described in Chapter 5, where mine companies were set up solely as a means of profiting from dealing in shares. The apparent existence of a large capacity to process ore on the surface could be part of an elaborate ruse aimed at reassuring investors as to the credibility and value of a mine; the installation of this machinery implying to those investors, whom De la Beche (1839, 325) described as 'unwary adventurers', that the production of tin was either already taking place, about to commence, or so overwhelming that extra capacity was needed. Of the examples cited, the companies that promoted Great Wheal Eleanor, Caroline Wheal Prosper, New Vitifer, East Vitifer and Holne Chase all went into liquidation having produced insufficient ore to cover costs. The expense of these installations of questionable necessity, must have contributed to the demise of these mines in no small extent, although under the circumstances of their origins the viability has to be questioned more broadly. No correlation can therefore be made between the existence of one or more stamping mills at a mine and its stage of development at abandonment or its output.

8.3 CALCINING

8.3.1 Calciners or burning houses

Conventional concentrating processes using the principles of specific gravity and water, cannot remove some of the impurities that are disseminated within cassiterite. The anonymous writer of 1671 (2212) mentioned that 'Mundick' (otherwise known as iron pyrites (FeS^2) or mispickel) was the main impurity 'some lodes being much pestered with it, others not at all'. To that may be added, according to Pryce (1778, 223), copper, lead, and Black Jack (blende or zinc sulphide (ZnS)). If these substances were not dealt with, the smelted tin could become brittle. The partly dressed ore therefore was roasted or calcined in a reverberatory furnace where the corrupting minerals or 'weed' were burned off as gases. For tin this process was usually referred to as 'burning' rather than roasting, as the latter term is more usually applied to sulphide ores of copper.

From earliest times it is quite clear from written accounts that only certain tin ores needed burning. The earliest is by Agricola who in 1556 stated that:

> *..it (tin) is burned if it is dark-blue in colour, or if pyrites and stone from which iron is made are mixed with it, for the dark-blue colour if not burned, consumes the tin*
>
> (Hoover & Hoover 1950, 348)

Accompanying this is a depiction of a furnace with description, in which the ore and fuel are placed in such a way that the burning fuel does not come into contact with the ore.

In 1671 the anonymous writer describes a 'Tin Kiln' serving the same purpose at Devon and Cornwall tin workings; this comprised a structure housing two horizontal slabs of moorstone placed one above the other about one foot (0.3m) apart. A fire is set under the lower stone and the heat passes through a gap at the rear. Tin ore is fed onto the lower stone through a central hole in the upper stone. The furnace was often drawn by a flue and chimney stack, usually not far from the building. This essentially is the layout that would be used for all future reverberatory calciners, but ironically, although describing Cornish and Devonshire practice, no field remains which fit this type have yet been recorded on Dartmoor of this period. However, this writer also adds that this device was only used 'when we perceive much Mundick in our Tin' (Anon 1671, 2111-2), a point reiterated by Kalmeter over 50 years later, when he wrote that burning occurred 'in places where the ore is mixed with mundic' (Brooke 2001, 64).

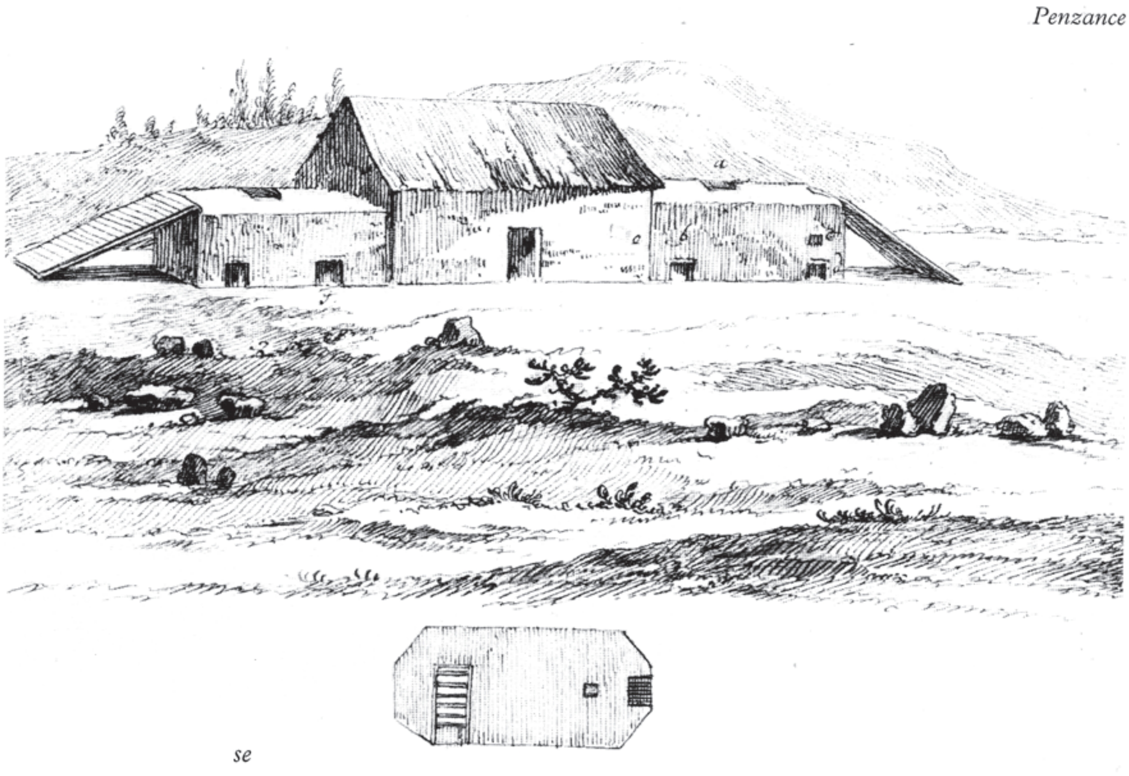

Fig 8.18 Sketch drawing of a Cornish burning house as observed by R R Angerstein in his Travel Diary of 1753-5. The ore was barrowed up the ramps and tipped through openings in roof of the burning chamber. (Berg & Berg 2001)

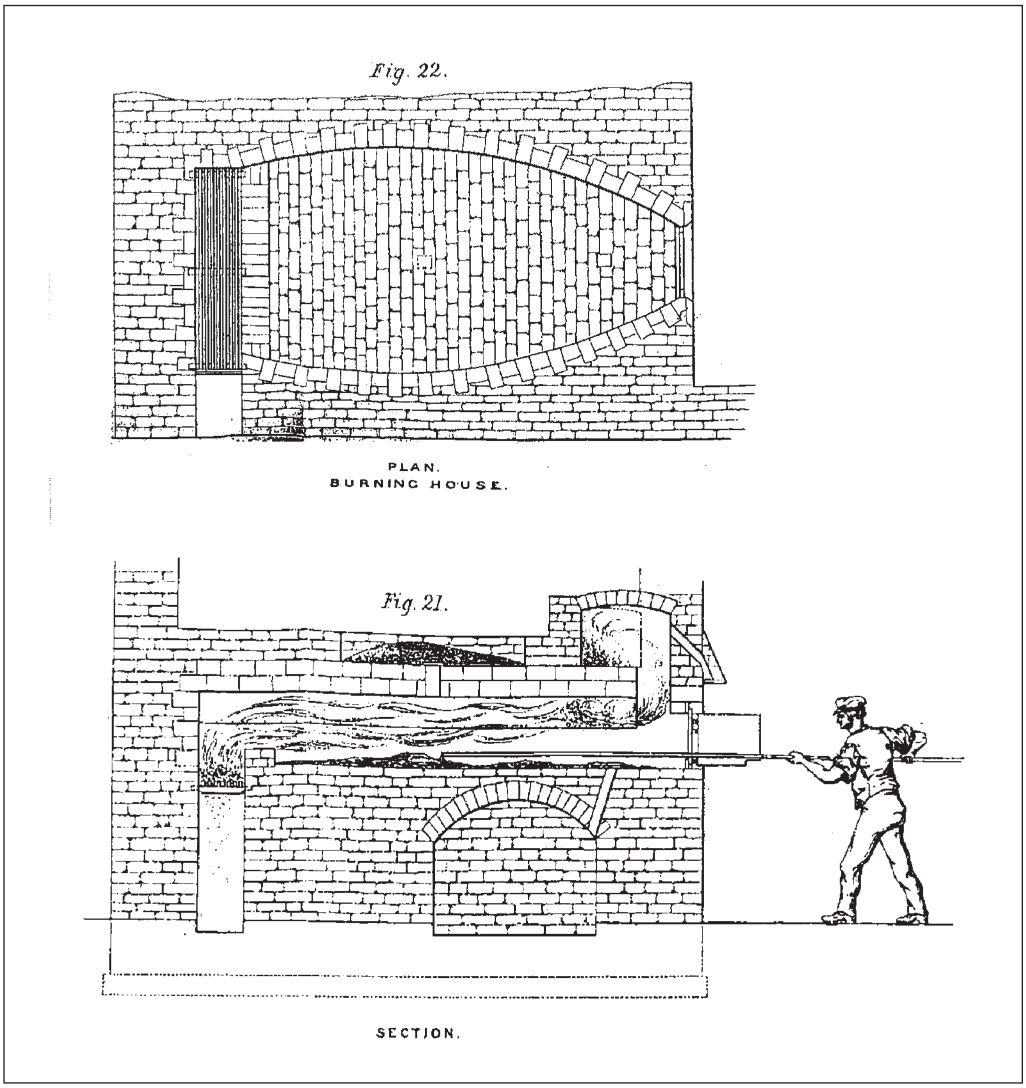

Fig 8.19 Section drawing and plan showing the interior of a reverberatory calciner or burning house from Henwood 1832.

During Angerstein's visit to Cornwall in 1753-5, he witnessed the use of burning houses where 'the ore that is contaminated with sulphur and copper must be calcined' and he provided several informative drawings (Fig 8.18) of burning houses of the period (Berg & Berg 2001, 106-7). Pryce (1778, 224-5) provided a lengthy description of the use of the burning house, used for 'tin that is corrupted….' as opposed to 'clean work'. Henwood, writing in 1832, claims that 'the greatest part of the tin-ore produced in Cornwall needs roasting' (Henwood 1832, 153), a point repeated by Henderson in 1853 and Ferguson in 1873. It would seem that over time, the various authorities disagree as to the total amount of tin that needed calcining but the later writers err on the side of *all* tin requiring the process.

By the time of these later writings the reverberatory calciner was housed in a purpose-built structure and consisted of a burning chamber with a raised floor, a low vaulted furnace and a fire set at one end. At the other end was a flue and an opening through which an operator could rake the ore whilst it was being

TABLE 8.2 Calciners or burning houses

A	B	Mine Name	C	NGR	Date	D	Date Reference	E	Field Comments
3	1	Atlas	R	7810 7658	1890	ID	*MJ* 24.05.1890; MJ 27.09.1890	✓	Two burning chambers, one at each end of the building, and a central section with a ground floor entrance. Above the burning chambers, stone floors housed hoppers into which the dressed tin was placed then fed vertically through a charging hole into the burning chamber. The fumes passed up chimneys build into the end walls but a large external chimney stack was probably also used to help draw the fire. The chambers were accessed by small openings with iron doors on the walls of the central section. Iron tie rods to strengthen the walls pass through the two chambers, connected to vertical flat iron braces on the exterior. Access to the top of the hoppers was via an external stone staircase on the ends of the building. The chimney remains intact to its full height though is affected by ivy growth as is much of the main structure.
62	2	Smiths Wood	R	7731 7481	1859-63	OD	Hamilton Jenkin 1983,126; Brooke Index, Ilsington	✓	The structures survives mostly to foundation level though one building has walls surviving to a height of 1-2m. All have been adapted for use as garden features. A partially sunken stone flue may be traced from the west side of the ruined buildings, travelling in a straight line for approximately 100m. The flue is constructed with slab stone sides with flattish capstones to cover. It terminates at a chimney stack sited up the slope at SX 7732 7472. The stack is circular and slightly tapering and stands to a height of approximately 3-4m.
74	3	Little Gem	R	4945 7059	1870-75	OD	BI, Whitchurch	✓	The chimney does not survive and much of the structure has collapsed, however the front, south wall is still standing, up to 2m in places . Cut into this surviving wall is a 1.45m by 0.4m wide vertical slot with substantial stone quoins lining the opening, and to the east of it, at ground level, is an arched tunnel under the burning chamber or 'wrinkle' for unloading the calcined ore survies in situ.
32	4	Furzehill	R	5161 6912	1860s	E	-	✓	A possible calciner. The building has been adapted for other purposes but the brick-lined arch survives and evidence of the furnace floor, now removed, is visible on the interior
106	5	Devon United (1)	B	5117 7852	after 1884		OS 1884	✓	A pair of two calciners. Roofs and upper sections of walls now collapsed but much brickwork arounf the arches survives.
106	6	Devon United (2)	R	5118 7853	1884-1905	OD	OS 1st and 2nd Editions	✓	The upper section of the building is missing but the vaulted ceiling, furnace and access door all survivwe as does the bricked arch of the wrinkle
105	7	Wheal Freindship	B	5062 7946	after 1906	ID		✓	Not visited
98	8	Owlacombe	B	7698 7295				✓	Not visited
66	9	Whiddon	R	7530 7201	1757	OD	Ref. DBC 1/17/2 Cheshire Record Office	-	Not visited
67	10	Yeoland	U	5103 6612	1849	ID	*PDWJ* 08.02.1849	-	A barn now stands at the site marked as a burning house on the mine plan
98	11	West Beam	R	7652 7358	1845-51	OD	*EFP* 07.08.1845; DRO 1164b/11	✓	A much ruined building of single chamber type which is marked on the OS 1st Edition. Only the outline of the burning chamber is visible, covered by rubble. Stone caps of the flue survives in situ traversing the hillsope to the rear of the building though no trace of the chimney could be found.

A = site number B = burning house number (BH) C = type (R for reverberatory and B for Brunton) D = date status (ID = installation date; OD = operational date; E = estimated)
F = Field evidence surviving

burnt. The dressed ore was fed into the burning chamber from an upper floor through a small opening in the roof (Fig 8.19).

Henderson also remarked that the Brunton calciner was gradually coming into use in Cornwall and adopted at many of the larger mines, a point reinforced by Scofern in 1857. However, Ferguson claimed that of the two types of calciner in use in 1873, the Brunton was the 'older one' as newer designs were being introduced. But in 1894, Davies, although omitting to describe the Brunton, mentions and depicts the reverberatory calciner (Davies 1894, 423), which was clearly still a viable system.

The Brunton calciner, described by Henderson (1858), Scofern (1857) Ferguson (1873) and Truscott (1923), was a larger, mechanised variation whereby the floor of the furnace was made up of a circular, revolving table made from cast iron powered by a waterwheel. Coulters suspended above the table ensured the calcined ore kept moving and gradually moved it to the edge to be collected. Thus the process was continuous and needed an operator only to feed the hopper above. It was designed for a high throughput of ore, and as Henderson points out, its use was at larger mines (Henderson 1858).

Fig 8.20 A flue and chimney stack associated with the burning house at Smith's Wood Mine.

Fig 8.21 The burning house at Atlas in 2009. Although the upper story of the burning chambers is covered and roofed, the layout of this late 19th century examples differs little from that pictured in Angerstein's drawing of 1753 (Fig 8.18). However, as with most later examples, a chimney is attached at the rear of the building.

8.3.2 Calciners: field evidence (Table 8.2)

Despite the many technical writings on this subject and the implication from them that calcining was an essential process for some forms of tin ore at a majority of tin mines, the field evidence on Dartmoor is very fragmentary. Only ten are known and two of these from documentary evidence alone at Whiddon and Yeoland. It has not been possible to gain access to Whiddon, but this was the earliest documented burning house on Dartmoor, recorded in 1757 (CRO R/4998). At Yeoland Consols, a barn now stands at the location of a burning house depicted on the abandoned mine plan (AMP R153). Three mines, Wheal Friendship, Owlacombe and Devon United had Brunton calciners, two at each mine arranged in pairs. In all three cases however, their main purpose was for the production of arsenic (not covered by this thesis), which was a marketable product in the late 19th century, and all of these examples are of that approximate date.

As to reverberatory calciners, or burning houses, there are four certain examples and one possible where field remains survive. The smallest of these is at Little Gem (BH3) only 4m long with a furnace opening of 0.4m, which indicates a limited scale of output. At Smith's Wood, now within a private garden, only parts of the wall survive, but an intact stone-covered flue survives running up the slope to a small chimney stack which is still standing (Fig 8.20). Smith's Wood Mine was under development between 1861 and 1864 and for which there is no known record of production (BI, Ilsington) and field evidence confirms that it was barely developed underground. The presence of a burning house (BH 2) at a mine which is known to have raised only 6.8 tons of black tin (Burt 1984, 102) has the same implications as the prematurely installed dressing floors discussed above; its existence may have been due to either a miscalculation as to the potential of the mine, or it was installed to give the impression to would-be investors and existing shareholders that large amounts of tin for processing were anticipated. Either way its existence seems premature considering the known lack of development underground.

At Devon United (BH6), although the superstructure of the building is missing, the burning chamber has survived. On this example a long flue and stack are depicted on the 1905 OS 2nd edition map attached to the rear of the structure, though the stack does not survive. At Furzehill, a roofless structure, which was almost certainly a burning house, has been adapted for other purposes, possibly a barn, at some time in the past when the floor of the burning chamber was removed. At West Beam (BH11), a burning house built between 1845-51 survives as a pile of rubble though the stone built flue is clear running up the hillside and parts of the burning chamber certainly survive beneath the rubble.

The finest surviving burning house is at Atlas (BH1) where its later use as a hay barn has ensured its survival and it remains as a roofed structure, with the majority of its original features in place, including an intact chimney stack (Fig 8.21). The building has two burning chambers, accessed from a central covered room, and an external chimney stack. The furnaces were at the end of the chamber, with the access hatch for the operator at the other. A tunnel on the front of the building was the point from where the calcined ore left the building.

It is notable that all the recorded burning houses are located around the peripheries of Dartmoor away from the granite zone. This is almost certainly because tin extracted from the granite areas was uncontaminated by the sulphide elements of other metals, whereas tin formed within the Metamorphic Aureole was more likely to have copper, arsenic, mundic and blende residing alongside it in the country rock. This ties in with, and offers some explanation for, the testimony of contemporary accounts cited above, that not all tin was in need of this form of treatment. However, several tin mines within this peripheral zone where dressing floors exist have no evidence of a calciner. These include Holne Chase, Caroline Wheal Prosper and Wheal Mary Emma. It would appear that the chosen emphasis of the surface installations at these undeveloped tin mines varied.

8.4 COPPER DRESSING

For reasons explained above, the dressing of copper ores was traditionally less mechanized than for tin. In Borlase's description of copper dressing in 1758, he describes a series of manual operations involving sorting the ore (picking) as it came to grass on the criteria of richness and size; breaking the ore up with hammers (spalling); washing in a timber trough (strake). At this stage much of the best ore (prills) could be sold direct to the smelters without recourse to mechanical dressing processes. Once the best ore was thus sorted, secondary grades (dradge) would then be sent for re-sorting, further comminution (bucking), washing and jigging. Finally, according to Borlase:

> *The poorest or most stony parts, which are not fit to be put with the picked ore, are carried to a stamping mill, where pounded and passed through a rough grate; what ore rests in the forepart of the pit is carried back to the jigging searce and worked as before-mentioned; but what runs off to the hintermost part of the pit, and remains there, and in the second pit, is slimy and must be trunked, buddled, and tozed as the slimy tin.*
>
> (Borlase 1758, 203-4)

Essentially only the poorest ores, known as 'halvans', were subject to the mechanised processes, which were more or less the same as for tin, including stamping. As early as 1724 Kalmeter drew a line of distinction between 'clean' and 'stamping' ore (Brooke 2001, 47).

Pryce gives a similar though more detailed account, and again emphasises that 'Stampt Ore' is derived from only halvans, and he warns that the economics of dressing it can sometimes be questionable (Pryce 1778, 238).

By 1832 in Henwood's account for copper, neither the principles nor the mode of applying them had altered noticeably, despite the author's claim to the contrary; manual operations still dominated the process, except the stamping and buddling of the halvans. In his supplementary notes however, the crushing machine (below) is mentioned as having been introduced by 'Mr John Taylor at some mines under his management near Tavistock, about twenty years since' (Henwood 1832, 164).

There are at least 40 documented mines on Dartmoor where copper is recorded as one of the metals sought (Table 6.2) based mainly on information from Dines (1956, 52-7) supplemented by primary sources. Field investigation has revealed that of this total only a relatively small number have specific archaeological evidence for copper dressing. Several of these have an inordinately large quantity of

Fig 8.22 Dressing waste at Brookwood (left) and Lady Bertha (right) mines.

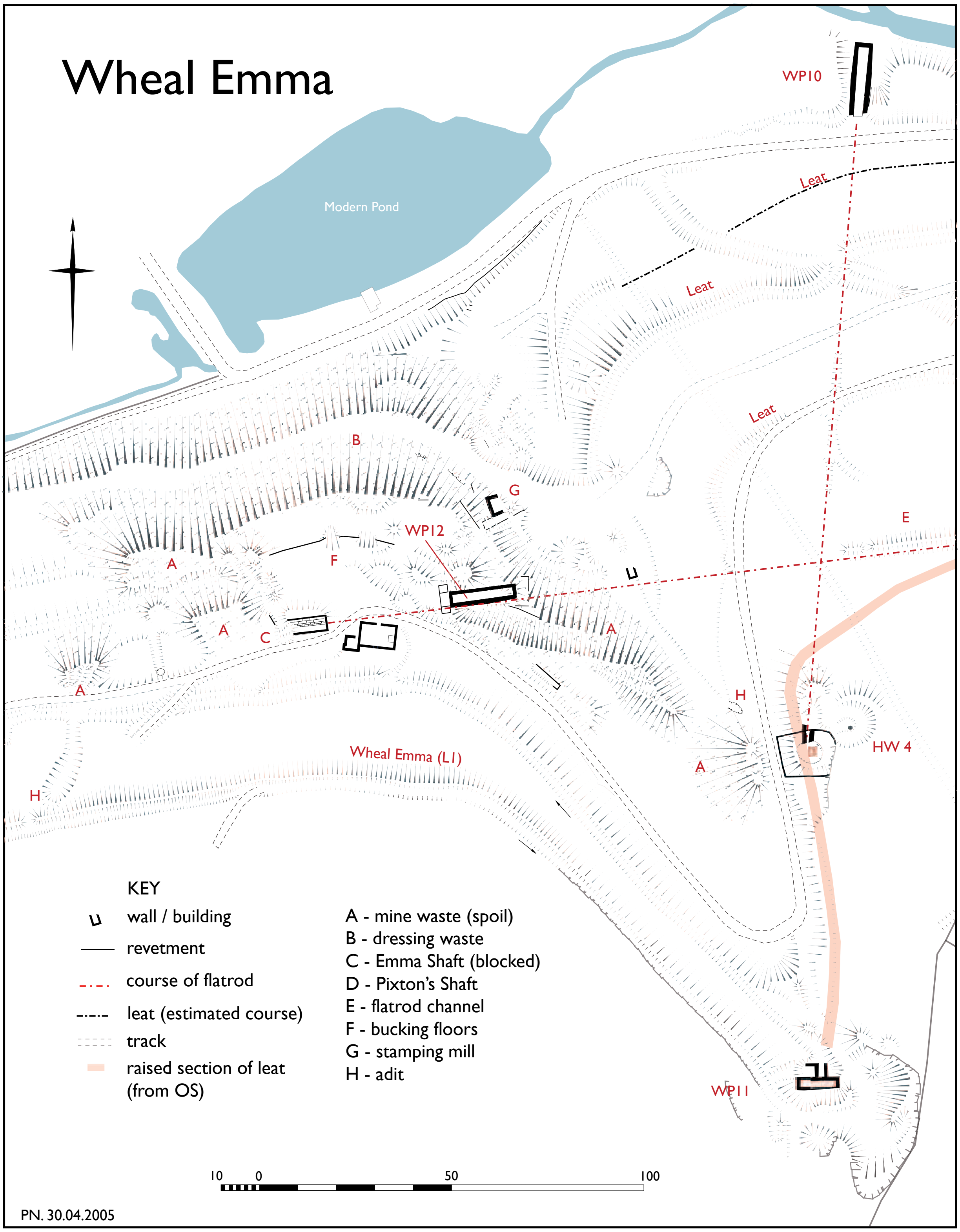

Fig 8.23 The central area of Wheal Emma mine. Showing the wheelpit of the large 50ft waterwheel installed in 1859 (WP12) following the building of the Wheal Emma Leat; large spoil heaps emanating from Emma and Pixton's shafts; dressing waste below the cobbing floors; the large wheel house which contained a 60ft waterwheel (WP10) to power pumps in Pixton's shaft, and other features as annotated.

dressing waste on site, especially at Ramsley, Brookwood (Fig 8.22a) and Lady Bertha mines (Fig 8.22b), suggesting high volumes of ore were dressed.

8.4.1 Stamping Mills at Copper mines

Evidence for stamping mills specifically at copper mines is not extensive among the sites included in the survey, but has been recorded at four mines. Ausewell (Fig 8.4), which has four very ruinous stamping mills (DF1-4), may be the earliest of these as described above. At Virtuous Lady a very ruined dressing floor (DF30) with backfilled wheelpit for a probable stamping mill survives but it is as yet undated. At Brookwood mine (Fig 7.29), a large wheelpit, adjacent to a levelled area at the top of the dressing area, may have powered stamps, and at Wheal Emma, there is a small stamping mill (Fig 8.23) with iron fixings for the stamps frame still *in situ* near the lower end of the dressing area. Field evidence suggests that these mills were no different in character to those of tin with which they were contemporary,

8.4.2 Crushing machines

Crushing machines, otherwise known as Cornish Rolls were, ironically, first introduced at a Devon mine by John Taylor at Wheal Crowndale, just west of Tavistock in 1806, and although only eight crusher houses have been recorded in the study sample, they comprise the major form of field remains specific to mechanised copper, and sometimes lead, dressing. They also represent one of only a few radical technological developments in ore processing of the early 19th century for which field remains survive, representing a change from the traditionally labour-intensive copper methods to one more mechanized. In Phillips and Darlington’s account of 1857 crushing machines are particularly celebrated for their ability to deal with ‘large quantities of dredgy or disseminated mineral’, in other words they were ideal for crushing middle and lower grade material (Phillips & Darlington 1857, 183).

The background to the development of the crushing rolls was outlined in 1873:

> *In the year 1806, the price of copper being then very high, that mine had produced a large quantity of ore which occurred much disseminated through the waste matter. There was not sufficient labour on the mine to deal with this quantity of material, although more maidens had been imported from Cornwall for the purpose; and one day his father (John Taylor) remarked, in answer to the apprehensions of his agent, “I will make a cast-iron maiden for you”*
> (Ferguson 1873, 138).

Clearly, if this account is accurate, Taylor designed the machine as a response to a unique convergence of conditions caused by the specific mineralisation of the mine in question (i.e. disseminated or middle to low grade), the economic urgency caused by the high price of ore, coupled with a shortage of labour to meet the demand. The machine was so well suited to the task that it was widely adopted, not just at copper mines but also lead mines, eventually becoming one of the key pieces of primary crushing machinery at mines worldwide. A drawing of a ‘crusher’ appeared alongside Henderson’s description

TABLE 8.3 Crusher House Field Evidence

A	B	Mine Name	NGR (SX)	Date	Date Status	Reference	Ores	Power Source	Wheelpit Dimensions	Internal Dimensions	Notes
1	15	Brookwood	7234 6748	pre 1875	depicted on AMP 1875	AMP RD66 D	Cu	Water	not known	not known	Now incorporated into woodshed at Brookwood Mill House.
2	81	Virtuous Lady	4737 6987	1859	for sale in 1859	*BI*, Buckland Monachorum	Cu	Water	8.3 x 1.5 x ??	4.9 x 5.6 x 3	Wheelpit survives at ground level only. Main building partly collapsed.
3	15	Brookwood	6176 6752	1875-86	not depicted on AMP 1875 but is on OS 1886	Newman 2005, 33	Cu	Water	9.7 x 2.2 x 5.7	not known	Crusher may have been attached to the SE side of the large wheelhouse (WP7), though it is more likely to have powered a hauling device.
4	74	New Victoria	7452 7150	1869	first mentioned in 1869	Newman 2003, 208-9	Cu	Water	19.1 x 1.5 x 7	5.2 x 4.6 x 4	Attached to the east side of the wheelpit (WP 1) is a ruined building standing in places to 4m. Some in-situ timber remains within the structure.
5	71	Lady Bertha	4721 6889	1855-68	for sale in 1868	*BI*, Buckland Monachorum	Cu	Water	10.8 x 1.5 x 3.6	5.5 x 4.8 x 1.8	Attached to the west side of the wheelpit. The sockets for the large timbers which supported the rollers are visible in the south wall.
6	61	Silverbrook	7890 7586	1857	for sale in 1857	*BI*, Ilsington	Pb/Au	Steam	n/a	n/a	Located on the eastern end of the mine complex, apparently powered by the whim engine (EH 10). Only low stumps of walls survive, filled with rubble.
7	28	Ramsley	6490 9300	1868	had been installed by	Hamilton Jenkin 1981	Cu	Water	10.9 x 1.2 X ??	not known	Diameter recorded in documents.
8	30	Yarner	7823 7833	1865	for sale in 1865	*EFP* 13. 09.1865	Cu	Water	not known	not known	Destroyed when area was levelled at unknown date.

A = Crusher House number
B = Site Number

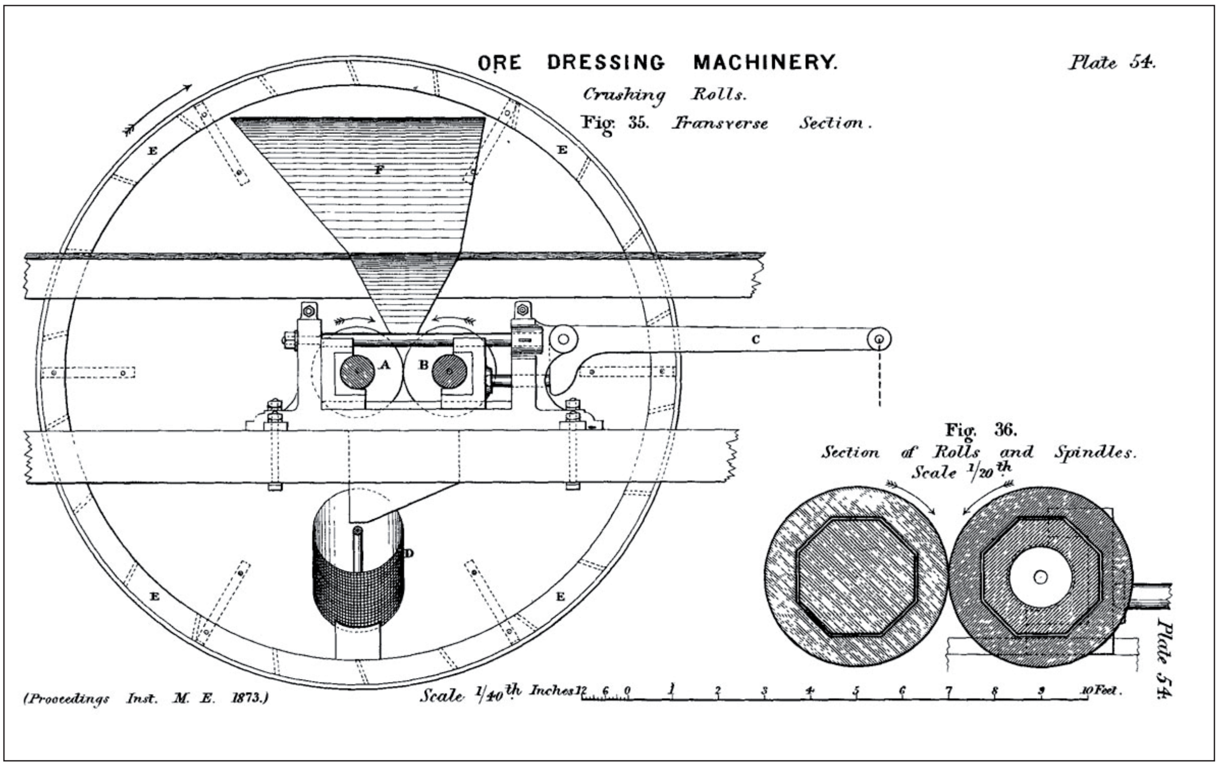

Fig 8.24 Elevation showing the principal components of a crushing mill or 'Cornish rolls' from Furguson 1876.

of 1853 but the machine had changed little in detail by 1873 (Ferguson 1873) (Fig 8.24). Crushers were still considered worth mentioning in Davies' 1894 treatise and were more or less unchanged in appearance apart from power supply. As late as 1923, Truscott also includes Cornish Rolls in his *Text Book of Ore Dressing* but by then, more developed types of roller crushers were being introduced.

The principle of the machine was that two iron cylinders or 'rolls' of the same diameter, with horizontal axles, revolving in the same plane but in opposite directions, were mounted in a frame so that they almost touch tangentially, the gap between the rolls being set to the required size of the crushed material; ore was fed in via a hopper mounted above the rolls. One of the rolls was fixed but the other could retract to prevent large or very hard lumps of rock jamming the machine and a sprung arm with a counterweight pulled the rolls together and maintained pressure (Fig 8.24). In the early machines, motive power was from waterwheels, though at some later mines steam engines were used.

Because of the considerable forces involved in the use of these machines they needed to be firmly mounted in a substantial timber framework. For this reason the majority of crushing rolls were housed in stone-walled buildings into which the timberwork was interlaced, providing a firm grounding. With all the timber and metal components removed after abandonment, the crusher house and the wheelpit survives as the main field evidence.

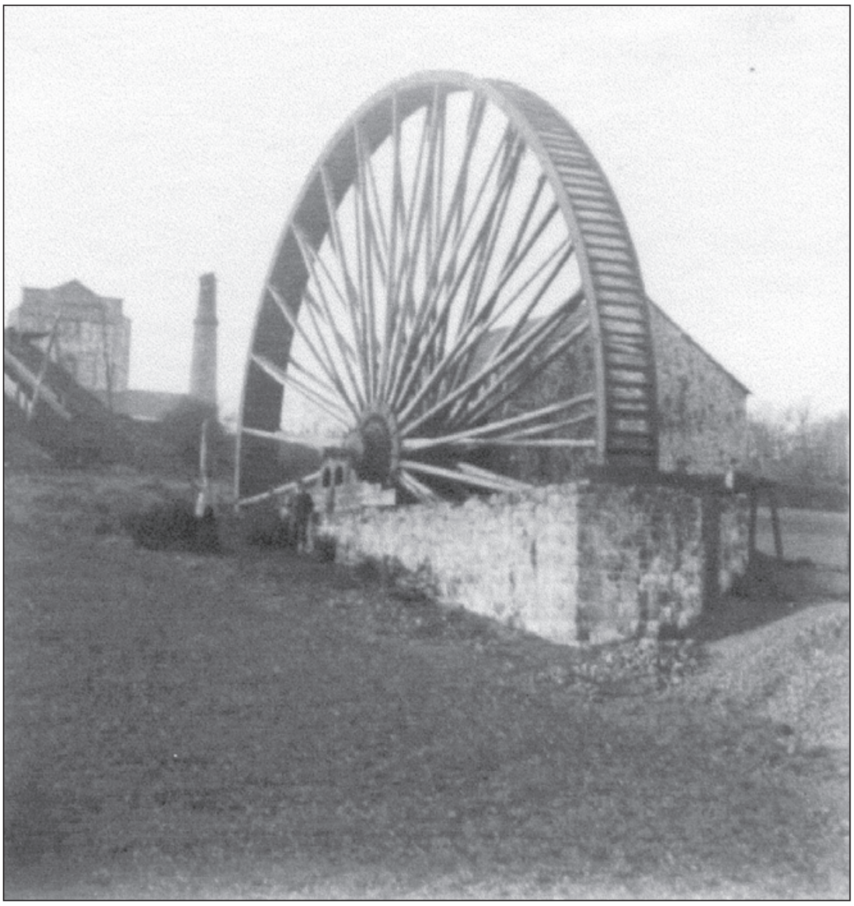

Fig 8.25 Photograph of Arundell Mine, undated but probably from about the 1880s or 90s after abandonment, showing the crusher house. The machinery was powered by a 60ft waterwheel. (see Fig 7.25 for layout). Photographer unknown. (courtesy of Mr & Mrs Heatley)

8.4.3 Field Evidence

Six crusher houses have been recorded within the study area (Table 8.3), though others are known through documentation but have since been destroyed. It is likely that more remain to be recorded at copper mines for which fieldwork has not yet been possible, such as Wheal Friendship at Mary Tavy, and the silver lead mines in the Plympton district; however, the number of unrecorded examples is unlikely to be high. The available dates for these crushers places their main period of use between the 1850s and 1870s, which coincides with a period of growth followed by rapid decline in Devon copper.

Of the six recorded, Ramsley (CH7) has been almost completely destroyed, though a photograph of it exists (DA 000456), and Silverbrook (CH6), the only known steam-powered crusher on Dartmoor, has been demolished and remains only as a stump. At Brookwood, the location of one house (CH1) is known from an abandoned mining plan (AMP R66D) but the structure has been absorbed into modern buildings. Standing remains survive at Lady Bertha (CH5), Arundell (CH4; Fig 8.25) which has a 19.1m intact wheelpit attached, and Virtuous Lady (CH2; Fig 8.26); contemporary photographs exist of the former two. No trace survives of the building at Yarner (CH8), where a crusher was recorded in 1865 (*EFP* 13.09.1865).

Fig 8.26 Remains of collapsed walls are all that survive of the crusher house at Virtuous Lady mine.

In all cases where field remains survive they comprise a chamber of approximately 5m by 5m internally, in which the rolls were contained, with an external attached wheelpit. The surviving wheelpits are between 8.3m (27.2ft) and 19.1m (62ft)long, but 10.8m (35.4ft) is the most common size if documented examples where field evidence has been destroyed are included; on average the wheelpits are 1.5m (5ft) wide. All surviving crusher houses are built from killas, the local stone of the Dartmoor border country, usually with robust walls up to 0.8m thick. Internal features include large rectangular sockets in the walls to house the terminals of the timbers which make up the frame of the machine. Ore to be processed was tipped into the hopper usually at the back of the building from elevated tramways. This tramway is visible on the photograph (DA 000456) of the Ramsley crusher. Entrances, where surviving, are located on the opposite wall to the wheelpit and through which it would have been necessary to barrow or tram the crushed ore to the next process.

8.4.4 Cobbing or bucking floors

Recognisable evidence for the hand dressing processes that played such an important role at copper mines is rare. Most earlier contemporary writers refer to sorting and breaking up the ore taking place as it came to grass, such as Borlase for example in 1758, who writes that the ore is re-examined upon being brought to surface where the best material is broken up or spalled with large hammers (Borlase 1758, 203). Much ore was then removed to be further hand dressed at bucking or cobbing floors, probably in covered sheds. This type of evidence is difficult to recognise at small copper mines as the waste product would be minimal. It is also a fact that some hand processes may have been obsolete by the 19th century at some mines with the advent of the crushing mill, which Henwood claims had mostly replaced bucking at larger mines by 1832 (Henwood 1832, 160). Technical writers (e.g. Henderson 1858) continued to write of these practices but by 1873, although sorting the ore was still done manually, the remaining processes were mechanised (Ferguson 1873, 133). But, as always, at smaller mines low-tech practices may have prevailed.

A series of levelled areas defined by stone revetment walls are visible at Virtuous Lady Mine. There is no evidence of a wheelpit or any other features, which makes these good candidates for floors where hand dressing processes took place. Similar evidence survives at Wheal Emma (Fig 8.23), where a large level terrace of over 42m long, close by the main hauling shaft, has a long revetted back wall. Below the terrace to one side is a spoil-covered slope, and at the foot of the slope is the remains of a small stamping mill. Ore having been hauled up the shaft was sorted and broken up by hand on the terrace, which was probably covered by a shed. Rejected material was thrown onto the spoil heap and the halvans sent down to the stamp mill. It is possible that all these fragmentary pieces of walling represent the base of a covered work area, the walls and roof of which were of timber. Henderson's illustration of women bucking ore shows the process taking place indoors (Henderson 1858, Fig. 7).

8.5 DISCUSSION

The mechanical crushing of tin and some copper ores on Dartmoor relied almost exclusively on the use of stamping mills; the principle on which they worked, with reciprocating vertical stamps powered by a waterwheel, remained unchanged from the 15th century to the 20th. Technological advances were essentially only of scale and capacity but for a few minor innovations. By the end of the 18th century and the beginning of the 19th, when mines such as Beardown, Wheal Katherine, Wheal Chance were operating, the field evidence demonstrates that stamping mills and associated dressing floors were constructed to a format which had been established at least by the 1750s, but still owed much to 17th and probably 16th-century antecedents. Thereafter the standard components and formulaic layout remained in use until the 1880s when the last examples at Hexworthy and Devon United were constructed and remained operational into the 20th century.

By 1800 larger waterwheels powered multiple heads of stamps, often on both sides of a wheel, and mortar stones, which had formed the base of earlier stamp mills, were obsolete. As the 19th century progressed, larger stamp batteries with greatly increased capacity were introduced. The classifying and dressing processes which dealt with the stamped ore became more refined with the introduction of, for example, the innovative methods of concentrating the ore and the circular buddle. However, the principles of separation in water using the variable specific gravities of the tin and the gangue remained unchanged. This continuity that is often evident among tinworking technology, which could be interpreted as conservatism and an unwillingness to embrace change, is perhaps better explained as a response to the sometimes marginal nature of mining; the adventurers adapted only when driven by necessity, such as for example the increasing problem of flooding which had spawned new innovations in pumping as mines penetrated deeper underground. But also, particularly in the case of the stamping mill and associated dressing processes, this was proven reliable technology and, on Dartmoor, water was available to provide power; as long as the parameters of the task remained constant, there was no reason to consider radical new methods, especially as increased throughput could be achieved simply by scaling up the operation.

The stamping mills of Dartmoor cannot be singled out as any more or less advanced than any other district. The field evidence when examined in the context of contemporary writings, which emanate mostly from Cornwall, negates any suggestion that Devon's mines were measurably technologically behind those of Cornwall. However, as has been established in earlier chapters, Devon's mines were on a much smaller scale by comparison, so the higher capacity installations powered by steam engines and designed for maximum throughput were infrequently adopted.

Innovation driven by necessity is more apparent in the case of the crushing machines developed for copper in the early 1800s. Although not numerous in the study area the total is representative of the number of copper and silver-lead mines where production was sufficient to warrant the investment. Although it is known that they were first developed in 1806, none of the recorded examples has been dated with certainty to before the 1850s, coinciding with the peak of copper activity on Dartmoor in this and the following decade. The high level of crushing mechanization at Dartmoor's copper mines is indicative of generally middle to lower grades of ore.

The distribution of calciners has demonstrated that their use was restricted to tin ores extracted from the so-called sulphide zone (Dines 1956, 23) away from the granite and within the Metamorphic Aureole, where minerals contaminating the ore were more likely to be present. Given the apparent importance of calciners in these locations, the shortage of confirmed examples by comparison with dressing floors is puzzling. It is possible, though unlikely, that the ores produced at some mines within the Metamorphic Aureole were sufficiently clean not to require this process, or that partly-dressed tin from these mines was shipped out for calcining elsewhere. A third possibility backed up by the data is that tin mines in these locations that lack these installations, were never sufficiently developed to require them, although in the case of Smith's Wood Mine, where a calciner was installed although only 6.8 tons of black tin was ever produced (Burt et al 1984, 102), the reversal of this scenario may have different connotations which chime with the above theory regarding over-capacity of some dressing installations and further examples might be expected.

Ore dressing installations were essential components in the workflow of even the smallest productive mine. However, the presence of unnecessary surface machinery to process ores at mines not developed beyond the prospecting phases, as well as over-capacity at mines of moderate output, gives a strong indication that capital for investment in such equipment was not in short supply, especially in the early stages of these companies' often short existence. This practice was on the increase from the 1850s and into the 1870s but may have been following a trend started earlier in the century. For some mining companies therefore, development at surface was propelled more by the need to appear prosperous and productive to encourage investment than by the pressures of production. Developing the underground elements of a mine by sinking shafts and driving levels was a slow, laborious and very costly process which could take years whereas building impressive-looking dressing floors at surface could be achieved relatively quickly. The conservative attitudes of Dartmoor's adventurers and the linear trajectory evident in the technology is no more apparent than in the preference for water power for the main prime movers driving heavy machinery both above and below ground, compared with the slow uptake, late arrival and minimal impact of steam power in this district, which is almost non-existent at dressing floors. A combination of factors influenced this choice, which are, together with the field evidence of water power, the next subject of investigation.

CHAPTER NINE

WATER POWER

9.1 HISTORICAL AND ENVIRONMENTAL CONTEXT

After the metallic lodes, water is the single most important natural resource needed in mining; when in plentiful supply, water can be harnessed to power machinery via waterwheels and turbines and was essential for the running of steam engines. Also, many of the dressing processes developed for the ores discussed in this thesis relied on the principle of separation and washing in water, as described above. If the availability of water was limited then more expensive alternatives needed to be found, which increased costs. The presence of water therefore was influential in the choice of location for a mine and the layout of its machinery. It was also a consideration in the economics and had a role in the promotion of the enterprise. Mines employing ostensibly cheaper water power in preference to expensive steam engines, which incurred greater installation costs as well as the need to purchase and transport copious quantities of coal, could present a persuasive element towards a decision to invest.

The probable earliest use of waterwheels in the Devon tin industry was at the stamping mills of the medieval and post-medieval period described above in Chapter 8. Although water power was not the only choice to drive stamping mills by the 18th century, and despite the introduction of steam, it remained the main source of power for the duration of tin mining on Dartmoor and continued in use until the final demise of the industry in the early 20th century; steam was used at only two recorded stamping mills (section 8.2).

This may be indicative of the small scale of mining on Dartmoor and the limited capacity needed to process the ore by comparison with the large Cornish tin mines where massive batteries of stamps were installed powered by steam engines (e.g. West Bassett in Palmer & Neaverson 1989, 37). Nevertheless, stamp batteries of moderate size have been recorded, at Atlas (DF5) for example which had 24 heads in about 1900 (Greeves 2008, 36) and Haytor Consols (DF56), where 32 heads were said to have been installed in 1851 powered by a 30ft waterwheel (Hamilton Jenkin 1981, 132). Whether either mine needed this many stamps is debatable (see Chapter 8) but at both sites ample archaeological evidence remains to authenticate these accounts, and at Atlas a photograph of the stamps *in situ* survives (Greeves 2008, 36). Robert Burnard captured a disused stamping mill at Whiteworks, with 24 heads *in situ*, in a photograph of 1889; earthwork remains of this mill survive in the field (DF65).

As established technology the waterwheel was easily adapted to power the pumping devices needed when mines began to penetrate deeper than the limits of free draining adits. Water-activated pumps have their origins outside the west of Britain, probably in Germany in the mid-15th century (Hollister-Short 1994, 83). It is known that water-powered pumps were in use at the Bere Ferrers silver mines

Fig 9.1 A ruined wheelhouse at Huntingdon Mine, which powered pumps via a flatrod system in a shaft 527m to the north.

in Devon by the 1470s (Claughton 1996, 35), but the earliest references to specific waterwheels at Dartmoor mines, other than those powering stamping or smelting mills, are from Kalmeter in 1724 when describing the pumping facilities at Black Down lead mines described in Chapter 7, and the Marquise Mine near Tavistock (Brooke 2001, 12). The paradox of water becoming the principal source of power for pumps to remove water from mines, was noted by Barton (1968, 153), who has written the most important historical account of water power at Devon and Cornwall's mines. This writer considered that although water power had its heyday in Cornwall at around 1800, deeper mines and the advent of the steam engine meant that later in the century large waterwheels were gradually superseded by steam engines. In Devon however, where the mines were still relatively shallow, and the supply of water more reliable, waterwheels remained as the prime mover well into the 20th century. In 1838, the 50ft by 10ft breast shot pumping waterwheel at Wheal Friendship was claimed to be the 'most powerful in the world' (Barton 1968, 151). Other very large waterwheels for which field evidence survives, were installed at Brookwood (WP10) and Belstone (WP24) in the 1870s, and Devon United (DF75) where a waterwheel to power a dressing mill was still in use as late as 1920s (Richardson 1992, 53). Another notably large waterwheel was that of 60 ft diameter used to power the crusher at New Victoria (Arundell Mine) (CH5; Fig 8.25) in the 1870s and a 60ft diameter stamps wheel, which also powered pumps, installed at New Vitifer in 1870 (DF48) (BI, Chagford). There was also a great many smaller wheels used to power stamping mills and occasionally whims (Tables 8.1; 7.1).

Several Devon writers extolled the virtues of Dartmoor as a place highly suited to water power. John Taylor for example when writing of Devon's copper mines in his introduction to Risdon's Survey of Devon, claims that 'abundant falls of water made steam power unnecessary' (Risdon 1811, xx). He was not the first to make this observation however, as in 1787 William Warren had asserted:

> *Devon has water in such profuseness, that a Water Engine erected at the expense of from One Hundred and Fifty to Three Hundred Pounds is sufficient to Drain the Water from her mines to the above depth* [70 fthms].
>
> (Warren 1787, 3)

Although this statement must be understood in context, because Warren was attempting to promote Devon's tin mines over those of Cornwall, it is partly true. Cornwall was by this time becoming more dependant on steam, particularly in low-lying and intensively mined districts where the water resource was insufficient to supply the large number of deep mines operating. William Borlase had noted this as early as 1758, when outlining the virtues of the steam engine compared with the drawbacks of the water engine:

> *our superficial water in Cornwall (where we have few great rivers, and our brooks have no long course, and the mines are generally on the high ground) fails much; so that many of these* [water] *engines cannot work from May or June to October*
>
> (Borlase 1758, 171)

In Cornwall however, despite the environmental disadvantages, there was at least a partial water-power 'culture', which is not universal in all British mining districts. On the lead mines of Grassington Moor in Yorkshire for example, the small scale of mining in the post-medieval period had prevented the investment in such technology until the late 18th century and it was John Taylor who, having learned his water management skills at Wheal Friendship on Dartmoor, introduced elaborate water capture, diversion and storage systems to power large waterwheels (Gill 2004, 16). In the Derbyshire lead mines around the Derwent valley area, the limestone topography was a limiting factor in the ready supply of water (Willies 2004, 36), which ensured the slow development of water power. The high rainfall, underlying granite geology and blanket bogs of upland Dartmoor ensured a very different set of circumstances for this district.

The economic advantage of Dartmoor's water resource remained a theme of mine company promotions well into the 19th century. Where promoters of mines could boast to potential shareholders that a mine had its own plentiful water supply, which would imply lower costs. This point was overstated somewhat by the promoters of Great Wheal Eleanor who at the launch of their share issue in 1875 claimed:

> *The position of the property, the nature of the ground through which the lodes run (decomposed granite), and the plentiful supply of water for working (Winter and Summer) the Wheel and Stamps, obviate all that most expensive outlay for Engines and Coals to work the same, the water power alone being fully sufficient to perform all the work necessary.*
>
> (*EFP* 27.01.1875)

Fig 9.2 A partly ruined wheelhouse at Great Wheal Eleanor which provided power to a flatrod system as well as supplementing a steam engine to power a stamping mill. The moss-covered revetment of the dressing floor is visible on the right.

In fact, field investigation has demonstrated that the only supply of water at this site issues from the adit, which was itself created by mining operations, and contrary to their own statement, the adventurers later opted for a steam powered stamping mill, the engine house (EH13) of which remains to foundation level. What these type of promotions also fail to mention is the cost of licenses issued by landowners to extract water; a cost which in some cases could have equalised the disparity in running costs between water and steam power (Barton 1968, 154).

At Brimpts Mine the water capacity was seriously overestimated when two waterwheels, each of which powered a pump rod and a stamping mill, were installed and supplied by a single 6km-long leat from the Cherry Brook, but in 1853 there was sufficient water to drive only one wheel efficiently (Bird & Hirst 1996, 24).

Other promoters were more realistic about their claims for the use of water. At Brentor Mine the prospectus of 1860 reported the shortcomings of the water supply to the pumping wheel and mentioned the recommendation of one expert that a steam engine would be more reliable (*MJ* Nov 1860).

9.2 LEATS

Waterwheels used at Dartmoor mines were, without exception, overshot or pitchback, whereby water was delivered to the top arc of the wheel. A third variant, the breast wheel, has not yet been identified among recorded examples for this study area, neither has the undershot wheel which was almost certainly not used in this district. The choice of these variants was not made randomly; Smeaton had evaluated the various characteristics and efficiencies of each type of wheel in the mid-18th century (Smeaton 1759, 100-38) and his findings were well known to the mining community after that date. In the late 19th-century one technical writer explained how specific waterwheel types should be chosen on the basis of the reliability and volume of the water supply (Lock 1890, 5-10). On Dartmoor, sources of water are numerous but not seasonally reliable, their volume being much reduced in the summer months. The overshot wheels were favoured therefore but often needed head ponds to function consistently.

Overshot waterwheels required artificial watercourses or 'leats' to supply them. The use of leats to divert water to mineral operations has origins in the medieval period on Dartmoor when water for streamworks, openworks and tin mills was provided by narrow leats which were cut to divert streams and springs to the workings (Newman 1996; Gerrard 2000). Where supplies were at a premium, water could be stored by throwing up earthwork banks or dams against the hillslopes to contain the water in small reservoirs (Gerrard, 2000, 74). Documentation for early streamworks and openworks is rare but by at least the early 16th century some workings are recorded by name (Greeves 1981, appendix 1); any leat that supplied them with water can be dated by association. Some of these pre-18th century leats demonstrate great survey skill by those who created them in diverting the limited supply of water available on the high ground over great distances across difficult terrain. Particularly impressive examples may be seen in the Birch Tor and Vitifer area where scores of the silted channels which remain may be traced, some up to 2km in length, negotiating the sides of valleys and traversing ridge tops to convey the meager supplies (Newman 2002, Fig 4.1).

A tradition and a skill-base for surveying and cutting extensive leats for mining purposes evolved to accomodate the topographical requirements of the landscape of Dartmoor and its water resources. This tradition was well established by 1700 and thereafter, water was needed solely to power waterwheels and facilitate ore dressing, although the volume required had risen incrementally as the size and number of waterwheels increased.

9.2.1 Field evidence (Table 9.1)

(Nb. Only the longer or more complex leats are listed in Table 9.1. Other leats are indexed along with associated wheelpits 'WP' and stamping mills 'DF' in the relevant tables)

Earthwork field remains for leats of the 18th-20th century are generally wider than earlier leats, due to the

TABLE 9.1 Leats serving 18th and 19th century mines

A	B	NGR (SX)	C	Mines Served by Leat	D	E	F	Date Cut	G	Date References	Water Sources
1	3	6227 7097	2	Wheal Emma; Brookwood	7	19 km	P,S,C	1859	D	Levy 2005	Swincombe, Mardle
2	1	6999 6627	1	Caroline Wheal Prosper	2	450 m	S,P	1854	D	Hamilton Jenkin 1981	Dean Burn
3	1	7327 7054	2	Queen of the Dart; South Plain Wood	3	2 km	P	1849-55	D	Hamilton Jenkin 1981	Dart
4	2	7285 7178	1	Ausewell	4	750 m	S,D,Sm	mid 18th C	E		Dart
5	1	7108 7059	1	Holne Chase	1	540 m	S,D	1874	D	Newman 2006	Dart
6	3b	6236 8429 6253 8118	3	Birch Tor & Vitifer; Wheal Caroline; Golden Dagger	10	15 km	P,S,D	1793 extended 1823, 1832	D	Dickinson 1975; DRO 924b/B2/1	East Dart, Winneys, Down Brook, Statts Brook, North Teign, Varracombe Brook, Redwater
7	1	5309 6992	1	Furzehill	2	1.2 km	D	1796	E	Dickinson 1975; DRO 924b/B2/1	Black Brook
8	1	5146 7403	1	Wheal Surprise	1	300 m	P	1852	D	BI, Whitchurch	Taviton Brook
9	3	5556 7767	3	Sortridge; Wheal Fortune; (?)North Wheal Robert	3	9.58 km	P,C,S		n/k		Walkham
10	3	5416 8762 5452 8511	2	Wheal Betsy; Gibbett	n/k	13 km	P	1790s	E		Doe Tor Brook, Lyd
11	3	5500 8301	3	Wheal Betsy; Wheal Jewell; Wheal Freindship	>7	4.9 km	P,H	1791	D	Dickinson 1975; DRO 924b/B2/1	Tavy
12	3	4909 7082	2	Virtuous Lady; Lady Bertha	7	3.65 km	P,C,S	1856	D	MJ 17.05.1856	Walkham
13	2	5034 7030	2	Walkham & Poldice	1	993 m	P,S	1825	D	Dickinson 1975;DRO 924b/B2/1	Walkham
14	1	5927 7791	1	Beardown	1	1.74 km	P,S	1797	D	Dickinson 1975; DRO 924b/B2/1	Cowsic
15	2	5772 7201	1	Keaglesborough	2	2.24 km	S	1816	D	Dickinson 1975;DRO 924b/B2/1	Hartor Brook, Meavy
16	2	5897 6989	1	Keaglesborough	2	1.78 km	S	1816	D	Dickinson 1975;DRO 924b/B2/1	Newleycombe Lake
17	2	6545 9127	1	Ramsley	2	1.8 km	P,C	1850s	D	BI, South Tawton	Shilley Pool
18	1	5323 8635	1	Wheal Mary Emma	1	1.4 km	P,S	1850	D	MJ 12.01.1850	Lyd
19	2	6090 7185	1	Whiteworks	n/k	1.25 km	S	1786-1816	D	Dickinson 1975;DRO 924b/B2/1	Strane
20		6314 7015	1	Whiteworks	n/k	3.6 km	P,S	1786-1816	D	Dickinson 1975;DRO 924b/B2/1	Swincombe
21		6102 7009	1	Whiteworks	n/k	880 m	P,S	1786-1816	D	Dickinson 1975;DRO 924b/B2/1	Nuns Cross Stream
22	2	6349 7690	1	Brimpts	2 ? 3	6 km	S,P	1806	D	Dickinson 1975;DRO 924b/B2/1	Cherry Brook
23	2	6215 9314	2	Belstone	2	1.85 km	P,?	1878	ID	Hamilton Jenkin 1981	Taw
24	3	5162 7898	1	Devon United, South, Central	n/k	622 m	P,S,T,O	after 1886 (?)	ID	OS 1886	Tavy
25		6113 6640 6088 6827	1	Eylesbarrow (Engine)	4	5 km	P,S	1814-16	D	Newman 1999	Plym, Langcombe
26		6064 6779	1	Eylesbarrow	3	2.64 km	P	1804	D	Newman 1999	Plym
27		6538 6719	3	Huntingdon; Wheal Emma	-	7.31km	P,S	1812	D	Dickinson 1975; DRO 924b/B2/1	Avon
28	1	6265 9352	2	Belstone	1	780 m	P	1878	ID	Hamilton Jenkin 1981	Taw

Column A = leat No; B = type; C = total mines supplied; D = total waterwheels supplied ; E = approx total length (including all branches); F = purpose (P = pumping; S = stamping; H = hauling; C = crushing; O = other); G = date status (D = documented; I = inferred from (various) documents; E = estimated)
NB. This table represents only the major Dartmoor mine leats. Field evidence has been recorded for many shorter leats which supplied the smaller mines and individual water-powered installations which are not listed here.

Fig 9.3 A disused section of rock cut leat which diverted water from the River Dart to Queen of the Dart copper mine.

need for greater capacity. They are also less heavily silted as a result of their more recent abandonment, providing earthworks that are sharper, more clearly defined and usually readily identifiable as of a later date than those associated with streamworks and early mills, which are often difficult to trace due to silting. Typically a mine leat will comprise a channel of between 1m and 3m wide with vertical or slightly battered sides, between 0.5m and 1m deep. Surplus material excavated while cutting the leat was dumped on the downslope side to form a linear bank, which provided additional depth. Occasionally, sections of the interior sides of the leat are strengthened with a stone lining. At Caroline Wheal Prosper the entire 450m length of the leat earthwork (L2) has a stone lining on the downslope side, to prevent slumping and leakage on this moderate slope.

Dartmoor mines were never far from a water supply but within the confines of the mine's locality, water-powered installations had to be sited in such a way as to utilize the available water to the best advantage. Only approximate figures regarding inclination of the leats are available but most commonly they followed a gentle gradient, to prevent the water surging, and to maintain as much height as possible, especially in low-lying valleys or where the water was to be used over several waterwheels. The length of the leats depended on the volume of the river supplying it and the steepness of the riverbed, which would dictate the distance of the waterwheels from the source. Some leats drew water from a single river supply; these were usually for the smaller mines with limited water requirement, such as a single waterwheel, as at New Vitifer (DF48) and Wheal Mary Emma (DF50), or they were at locations blessed with copious rivers, such as Ausewell Mine (DF1-4) beside the River Dart. Where more water was required, or the available sources were very meager, several sources were tapped with separate leats from each source diverging into one major leat. The old Wheal Emma leat (L28) is such an example where two tributaries of the River Mardle contributed to the supply (Fig 9.4).

In terms of the destination of the water, and how it was utilized, leats may be divided broadly into three types (see Table 9.1):

1. Single mine, single purpose leats: Leats cut to supply a specific mine and a single installation or water wheel. In the case of stamping mills the water would also have supplied the dressing processes and any small buddle wheels present. Shorter examples are Wheal Chance (DF11), Plym Consols (WP15), Steeperton (DF13), Walkham United (DF21), New Vitifer (WP44), whereas at Wheal Mary Emma (L18) and Beardown (L14), the water was diverted over a much greater distance.

2. Single mine, multi-purpose leats: Describes a scenario where the leat to a specific mine supplied several waterwheels. The water was utilized in parallel when plentiful, as at Ausewell Mine (L4) where four wheelpits (DF1-4) sit at right angles to the substantial leat (Fig 8.4), and Little Gem (DF 36) with three wheelpits, including a small buddle wheel. At neither site could water be reused on a second wheel. When water was at more of a premium, wheelpits were arranged in a series, taking advantage of the fall of a slope. At Eylesbarrow the 3.6km-long Engine Leat (L25) supplied a large pumping wheel (WP30) and three stamping mills (DF41-43) arranged in a sequence down the slope (Fig 7.14). Similar, though more modest, arrangements exist at Huntingdon (L27), Brimpts (L22) and Whiteworks (L19).

3. Multiple mine leats: One leat supplying two or more separate mines, each having one or more waterwheels. This arrangement occurred mostly in the more densely populated mining districts around the peripheries of the moor but the Birch Tor, Vitifer and Golden Dagger mines leat (L6) exemplify this scenario on the high moor where two major sources of water were diverted from the head region of the River Teign, over 6km to the north-west, using 15km of leats. It delivered water first to a sequence of four waterwheels in the upper Redwater Valley (WP36-9; DF17), powering hoisting, and pumping at Vitifer Mine (Fig 7.8), together with a hoisting wheel above a shaft at Golden Dagger (WP40), supplied by a branch leat. The water from all these wheels was then ‘dumped’ back into the Redwater Brook, to be diverted via additional leats to supply a series of four stamping mills in the lower parts of the valley (Newman 2002, Fig 4.1).

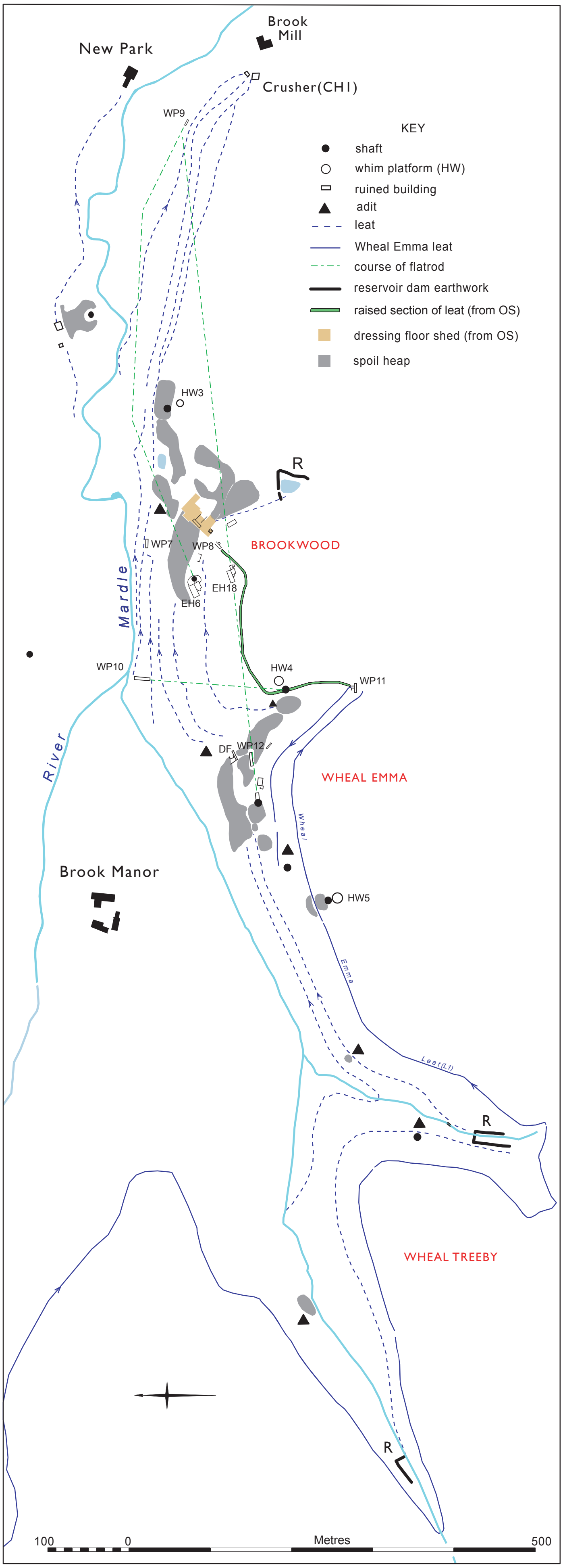

Fig 9.4 Simplified plan showing the contrasting sources of power at Brookwood and Wheal Emma mines. Waterwheels working during earlier phases of activity were supplied with water from the River Mardle and a small unnamed tributary which was dammed in two places to create holding reservoirs. A third dam collected water from a spring to the south of Brookwood Mine. These resources proved insufficient, particularly for Wheal Emma at slightly higher altitude and the Wheal Emma Leat (L1) was created in 1859 to divert water over 19kms from the River Swincombe on high Dartmoor. The earthworks of the earlier leats appear to have become partly buried by the later spoil heaps, but it is likely that at least some of these supplies were maintained using elevated timber launders.

In 1868 the Brookwood adventurers choose to adopt steam for pumping (EH6), although following abandonment of Wheal Emma in the early 1870s and amalgamation of the two setts in 1878, the new company (South Devon United) constructed a timber leat to divert the Wheal Emma leat to the Brookwood wheels and at least two new large waterwheels (WP10; WP8) and a steam whim (EH18) were installed. (source Newman 2005)

9.2.2 Examples and case studies

On western Dartmoor, around and to the north of Mary Tavy, a series of important mines with complex system of water supplies is contained within the valley of the diminutive Cholwell Brook. The mines include Wheal Jewell and Black Down Mine (Wheal Betsy) both documented from Kalmeter's visit in 1724 (Brooke 2001, 10) but working sporadically into the 19th century, and Wheal Friendship, Dartmoor's largest copper mine where deep mining occurred between 1796 (Barton 1964, 84; 91) and 1925 (Richardson 1992, 36). It has not been possible to carry out detailed fieldwork at Wheal Friendship, and much of Wheal Betsy and Wheal Jewell have been levelled. However, it is recorded in 1838 that Betsy and Friendship combined had a total of 17 waterwheels running (Watson 1843, 55). The earthwork remains of the leats survive over the open moors and through farmland, where several have been adapted for other uses. Some of these together with later installations and their water supplies are depicted on the OS 25-inch 1st and 2nd edition maps. Two major leats supplied these mines diverting water from neighbouring river valleys of the Tavy and the Lyd. Their water being used either directly on the wheels at Wheal Jewell and the higher wheels of Wheal Betsy, or indirectly by augmenting the flow in the Cholwell Brook. From there additional leats were cut to supply specific waterwheels.

Occasionally a mine leat would be extended to serve a second mine. Such is the case for the leat originally cut to serve Virtuous Lady (L12). The latter leat was, in 1856, extended to serve Lady Bertha (*MJ* 17.05.1856) where, during a later period, separate wheels for pumping (WP46), hoisting (WP18) and crushing (WP19) were arranged in a sequence down a steep slope, all supplied by the one leat and all depicted on the 1906 1:2500 OS map (Fig 2.2).

9.2.3 Reservoirs and head ponds (GRs listed where examples do not appear in illustrations)

Storage of water in ponds or reservoirs helped maintain a steady flow of water, rather than relying on small streams, which were not capable of sustaining the volume needed, especially for larger wheels. Reservoirs fall into two types:

Type 1 (Dams) Enhanced head weirs for capturing water at sources where streams flows are limited. A dam would be constructed across a stream, behind which the water could build up into a sufficient volume to flow along a leat. At Wheal Emma and Brookwood, three such dams survive. Others exist at Steeperton Mine (SX 6130 8814) and East Vitifer has two (SX 7083 8226; 7058 8202). A very large earthwork dam survives at Haytor Consols (SX 7580 7584) and a stone example at Wheal Duchy (SX 5833 7363).

Type 2 (Reservoirs) Storage at the mine to provide 'head' to the waterwheels. Having been diverted to the mine, often over great distance, water could accumulate in a reservoir before being released onto waterwheels. Fine examples exist at Hexworthy (Fig 8.17) and Eylesbarrow (Fig 7.14); both comprise linear hollows with substantial earth and stone banks on the lower side, behind which water was contained and released through narrow sluice openings. At Great Wheal Eleanor (SX 7345 8334), a substantial earthwork dam was constructed between the adit portal, serving as the source of water, and the large waterwheel (Fig 9.3). At Brookwood, a large spring-fed reservoir was created by building an earthen dam across a valley, just above the dressing floors (Fig 7.29).

The Wheal Emma Leat (L1, Fig 9.4) provides one of the most informative example of a leat constructed to supply a moderately prosperous copper mine in the border country near Buckfastleigh. Wheal Emma (Fig 8.23) and its immediate neighbour Brookwood Mine (Fig 7.29) had competed for the limited supply of water from the River Mardle since the two separate mines were created in the 1850s, each working setts that had been explored since the late 18th century (Newman 2005), indeed this may be the location of the Buckfastleigh copper mine mentioned by Kalmeter as 'old' and 'abandoned' in 1724 (Brook 2001, 46). A leat had been cut to the mines before 1815 (DRO 1258M-SS-C(DL)E b4c), diverting water from the River Avon at Huntingdon Warren, some 6kms distant and a series of smaller leats diverted water from minor tributaries of the Mardle, utilizing the type 1 dams described above. For the larger, mid-19th-century mines, the water supply was still inadequate, especially for Wheal Emma located at slightly higher altitude, and in 1859 (Levy 2005) a 19km-long leat was constructed to serve Wheal Emma, bringing water from the River Swincombe, across Holne Moor to augment the River Mardle, from which a further leat diverted the water to the mine. In 1868 the Brookwood adventurers choose to adopt steam power for pumping at their sett, although following the abandonment of Wheal Emma in the early 1870s and amalgamation of the two setts in 1878, the new company (South Devon United) constructed a timber leat to divert the Wheal Emma leat to the Brookwood wheels and at least one new large wheel (WP8) was installed (Newman 2005, 20). A steam whim was also installed but, despite the need for steam at Brookwood, it is recorded that the water-powered pumps remained connected (AMP R 66D) and were used to augment the engine at times of plentiful water, thus saving on coal and demonstrating the continuing economic precedence of water power over steam in this district.

9.3 DISCUSSION

By 1700 and the commencement of this study, the skills and knowledge of leat building acquired through supplying tin streamworks, openworks, stamping mills and blowing houses in the medieval period and later, were embedded into the mining methodology and traditions of the Dartmoor district. As underground mining methods advanced in the 18th century, necessitating larger and more numerous waterwheels for pumping, hoisting, stamping and crushing, the capacity of the leats needed to increase commensurately and these skills were expanded. Certainly from about the 1780s, though possibly earlier, mine companies surveyed and constructed leats that extended over increased distances across undulating moorland terrain, utilizing major and minor water sources as available. They also established reservoirs to capture the water to employ the resource in the most efficient way.

The natural abundance of water undoubtedly contributed to the continuity of this tradition and was among the attractions of Dartmoor for mine adventurers, as may be established from documentation such as Warren's pamphlet in 1787. Although not unique to Dartmoor, this water-power culture was less intense in some other mining districts in Britain, where environmental limitations or historical antecedent differed. But the economics of an apparently continuous source of power increased the potential of shallow marginal mines to become viable, in concept at least. It is certainly questionable whether the working of some locations would have been considered at all had the option of water power not been in place, and for those mines that were started, the location and layout of dressing floors and pumping installations was influenced by the nature of the available water supply. For larger mines resident on the borders of the moorland, such as Wheal Emma, Sortridge Consols and Wheal Friendship, numerous large waterwheels and the construction of an extensive leat system diverting water for many kilometers from the high moors was often still the most viable alternative for the powering of machinery, thus for both these reasons, steam engines were relatively uncommon on Dartmoor, although with exceptions. Other choices, such as waterwheel size and configuration were dictated by a range of local factors but mainly the lie of the topography and the reliability and volume of the supply.

Here is a notable divergence in the technological narrative for mining on Dartmoor and other districts of the south-west peninsula, such as the Tamar valley and the western districts of Cornwall. In these more prosperous districts, where tin and copper mines were rich but frequently very deep, and suitable water supplies were at a premium, steam power was an essential component and although water power continued, the industry could not have progressed with this system alone. By contrast, water power was crucial to the survival of Dartmoor's mines of more limited depth and wealth, and maintained a presence at the fore of the mining scene until the early 20th century. This preference indicates that in marginal districts like Dartmoor, a standard model of progressive technological development cannot be taken for granted; although the economic potential of individual mines influenced the availability of the capital needed to invest in the technology to develop them, the unique environmental opportunities or constraints offered by the district have also to be considered if these choices are to be understood fully in context.

CHAPTER TEN
RESULTS and CONCLUSIONS

9.1 SUMMARY of RESULTS

Dartmoor's natural resources provided an environmental context in which a prosperous medieval and post-medieval tin industry could develop. Early success was assured by the extensive deposits of alluvial tin, a result of the particular geological conditions of this highland zone, combined with a wet upland climate supplying plentiful water with which to work them. However, when the alluvial tin became depleted and surface lode outcrops were worked to the limits of contemporary technology, the geology and environment dictated a different trajectory for the industry as the search for tin and other metals on Dartmoor went underground. The chronology of these developments is likely to extend across the 16th and 17th centuries and by the commencement of the study period in 1700 the transformation was well advanced. Thereafter, the profitability of mining was limited by the cost of developing the mainly shallow lodes within the granite mass, another product of the local geological conditions, as well as the generally poor to middling grades of tin and copper ores which emanated from Dartmoor's deeper mines of the Metamorphic Aureole. The natural wetness of the area, which had been an asset to the tin streaming process, hampered progress in mines and necessitated the additional cost of pumping to rid the lower levels of water. These facts combined to place the viability of underground mining of Dartmoor's lode ores into the economic margins in the context of metal mining on a national scale and thereafter a contraction of the industry in this locality became inevitable. However, these environmental conditions could also be turned to positive advantage and provide new opportunities. The undulating topography enabled mines to drain freely to a moderate depth, while the water supply available from the upland rivers, could provide the power needed for pumping and hauling when and if the mines were sunk deeper, and drive the many water wheels associated with ore dressing.

It was these specific geological, topographical and climatic conditions, which determined the extent, duration and substance of mining for metals on Dartmoor, where these elements proved to be both a constraint and a driver of innovation. Whilst human exploitation of this landscape therefore could never extend beyond its geological potential, the level of human engagement with the resources was governed by social agencies that were a product of local antecedents, broader traditions and global economic pressures; collectively these agencies conspired to shape the progress and distinctiveness of the mining industry and its material landscape in this district.

The progress of mining on Dartmoor, as deduced from the study of contemporary commentaries, reveals that the industry was not perceived as prosperous in the period examined by this study. Indeed the opposite is true as many observers from the 18th century onwards considered that on Dartmoor the working of tin in particular was moribund in their own time, although the region's past importance as a tin producer was firmly acknowledged. These accounts are reinforced by tin production figures which demonstrate that output was at its zenith in 1524 but by the mid 17th century was falling rapidly and, despite a small recovery which peaked in 1706, was insignificant by the mid 18th century in terms of both earlier figures and the national context (Lewis 1908, 252-8). The declining production and a lack of belief that the tin industry had a future by contemporary observers, can be explained by the depletion of the alluvial deposits and shallow outcrops, which for over 500 years had been the dominant source of mineral prosperity on Dartmoor. British tin production (Devon and Cornwall) was rising rapidly between 1700 and 1750 (Schmitz 1979, 160-9), but Devon as a whole contributed little to this total, which must have made its mining industry appear insignificant, especially to those writing with one eye on Cornwall.

The makeup of copper lodes dictated that hard-rock mining was the only means of its exploitation. This alone, regardless of other constraints arising through the historical agencies discussed by economic historians such as Burt (1991) and Hammersley (1973), prevented early industrial-scale growth of copper mining in Devon and Cornwall because of the capital investment needed to develop copper mines. Whereas those mining for silver, elsewhere in medieval Devon, had been sponsored by Crown investment (Claughton 1994, 54), and tin extraction had been accessible to free-miners thanks to the availability of alluvials, copper mines had no such advantages. However, by the first quarter of the 18th century, as technology allowed, a small number of shallow copper mines became established in the border country of Dartmoor and in Kalmeter's account of 1724 (Brooke 2001) he implied that copper mining had a future whereas tin was in decline. Despite Kalmeter's optimism in the first quarter of the 18th century, for the remainder of the century, mining for copper on any commercial scale in this district is lacking in the writings of contemporary observers.

On a global scale, one factor likely to have affected the development, prosperity and endurance of this mining district was the consumption of metals; within the study period (1700-1914) the demand for tin and copper was rising in the United Kingdom and elsewhere. Tin had been used as a constituent of pewter since Roman times but production increased in the medieval period and had peaked by the 17th century (Hatcher & Barker 1974, 279). A fall in consumption of this alloy in the early 18th century was offset by an increase in the production of tinplate after 1750, which would continue growing throughout the remainder of the study period (Minchinton 1957, 15). Although no single dominant source of copper consumption can be identified, its use was widespread within several industries and world production rose exponentially from 1700 – 1914 (Schmitz 1979, 61-71). The unwavering growth in the demand for tin and copper is an ever-present contextual consideration in this study but of more direct relevance to the fortunes of the Dartmoor district and its individual mines were the ore prices, which although closely linked to consumption were subject to major fluctuations (Schmitz 1979, 293-8; 268-71), often influenced by world events that affected the supply. The viability of an individual mine is a complex equation; the marketable value of the product at a given point in time is offset by the quality and fecundity of the ore and the cost of retrieving and dressing it. Dartmoor's tin and copper lodes were rarely high grade and were non-enduring at depth so this district's mining enterprises relied heavily on a good price of ore for their very existence.

Despite the continuous negative assessments for the prospects of Dartmoor's mining industry by contemporary observers, and a lack of primary sources to suggest that mining was occurring on anything other than a very minimal scale for most of the century, interest in tin and copper mining was rekindled in the later 18th century; one likely explanation would be the changing economic patterns caused by the wars with France. By this period however, the extractive methodologies and technology had become transformed along with the organisational and economic basis of mining itself.

The genesis and eventual impact of capitalism within the Dartmoor mining industry shares many similarities with that of the Cornish model, although this research has confirmed that the context of differing natural resources ensured a divergence from the standard narrative as espoused by writers who have focussed on Cornwall alone and provided a contrasting material landscape to the latter county; comparisons with Cornwall therefore have to be made with caution. The working practices and organisation of labour which had evolved around the customary rights of the medieval tinners in Devon and Cornwall, who were essentially free miners, was an early developing-ground for elements of capitalism, as the burden of labour and capital investment was eased by consortiums of working tinners and investors who exploited the streamworks and shallow tin lodes. As the capital burden increased with the further development of mines, the concept of joint adventure was well suited to this mode of operation and continued to evolve as a wider pool of investors increased the available capital; by the 18th century the cost-book company, and later the limited liability joint-stock companies, controlled the industry. Small groups of adventurers who formed these companies could attract outside investment to cover mine development, which along with all other tasks was undertaken by waged employees. This transformation was no doubt slow but economic historians such as Buckley (2006) and Barton (1978) consider that a demand for copper in the late 17th century, in the freed commercial world that was developing in that period was one of the drivers behind the development of deep mining, which increased the demand for capital at a time when more was available.

The capitalisation of mines on this scale was probably introduced to Dartmoor with the arrival of adventurers such as Coster in the early 18th century, although benefits to the industry, particularly copper, appear not to have been felt to any perceivable extent until the 1780s and 90s. However, following the years of lowered inactivity, the input of capital may be singled out as the most enabling of human agencies in the recovery of Dartmoor mining, allowing this poorly-endowed mineral region to be revived and for persistent attempts at metal mining to continue.

As shares in mines developed a monetary value independent of any expected returns on the investment from mineral sales, so the commodification of mine shares becomes an additional economic consideration in the study, as the motivation behind mining enterprise underwent a partial and subtle shift. Certainly by the 1790s, although probably earlier, attempts were underway to attract 'out adventurers' to invest in Dartmoor's mines. Encouragement to participate in these mine adventures was often undertaken on the basis of embroidering the traditions associated with the district. Mine adventurers interpreted the landscape evidence of past mining very differently to other commentators, presenting the works of the 'old men' as places which had been under-exploited and ripe for further development. The advantages brought by improved underground and surface technology and a misplaced belief in the potential of Dartmoor's mineral resources were argued persuasively by those keen to gain support for their enterprises. The variety of field and documentary evidence for mines on Dartmoor suggests that while some mines were enduring and moderately productive, others were not. Without detailed documentation for individual enterprises it would be unfair to be critical of the motives of all Dartmoor's mine adventurers as deliberately selling a myth. However, there is definite evidence that some mines were set up as scams, whereby the 'in adventurers' made their profit by off-loading shares to 'out adventurers', in mines that were not capable of sufficient production to ever be profitable. But there are also grounds to believe that many mines were set up as genuine concerns, designed to bring prosperity to the adventurers and local businesses supplying goods and services as well as providing employment, albeit often of a non-enduring type.

By the first quarter of the 19th century a pattern had developed whereby the level of activity associated with mine adventure corresponded to the fluctuations in ore prices and was manifest by the creation of new mining companies during periods of increase, and closures at times of falling prices. The activity took place on two entrepreneurial levels: in some cases these were renewals of established mines, capable of producing ore and enabled by the increased returns. In other cases they were scams, centred upon mines of no real potential, whose adventurers capitalized on the speculative climate that accompanied rising ore prices. Despite the expressed doubts of those experienced in mining, this cycle continued throughout the 19th century and into the early 20th, the operation of some mines being episodic rather than continuous, though less and less mines operated as a final decline set in towards the end of the study period.

Detailed historical narrative for individual mines has not formed part of the methodology used in this thesis. However, the broader historical contexts established and presented above, together with some outline details of individual mine chronologies and a collective general analysis of primary and secondary documentation has been undertaken. This data has provided a sound basis for a theorized model within which the material evidence of landscape intervention may be interpreted in terms of an expression of capitalism, shaped in no small way by the opportunities of the local environment.

Exploiting tin lodes had been occurring on Dartmoor since at least the 15th century and the use of openwork and pit working techniques, for which extensive evidence survives in the field, was well established by the 16th. The precise date of underground mining using shafts and adits cannot be determined but it was probably not widespread in this district until the 17th century and even then was not common on granite. It was, however, the established mining technique for tin and copper by 1700. Although some documentation confirms that mining for both metals was occurring at this time at locations such as those listed by Kalmeter in 1724 (Brooke 2001), and by others later in the 18th century, archaeological evidence for mining which can be confidently dated is at a premium until the 1780s, when the recorded 'revival' occurred. The majority of field evidence cited for this thesis represents remains of activity occurring between that period and the early 20th century. The primary landscape evidence for extraction is the surface remains of underground activity and for the dressing of ore; the study of these remains has provided an outline of the extent and materiality of mining operations which complements the historical data.

The scale of surface evidence confirms that although several mines may be considered small- to large-scale, the great majority known from documentation or field evidence, which make up the sample for this thesis, were worked on a lesser scale, many proving only to be prospects or developed prospects. Among the major diagnostic element to determine this factor is the mass of the spoil heaps, from both underground activity and dressing, which provide clues as to depth and endurance of a mine, with the caveat that they cannot determine its level of economic success. On this basis, only a handful of tin mines have sufficient surface evidence to suggest extensive underground activity and only at two locations within the granite zone (Vitifer and Hexworthy). For copper mines, only Wheal Friendship (which did not form part of this survey but has been sufficiently recorded by others such as the OS for the extent of field remains to be estimated) may be considered a large-scale productive mine, with Ramsley, Wheal Emma and Brookwood also having evidence of less-enduring large-scale activity. The absence or limited mass of spoil at a number of other mines is indicative of lack of underground development.

Other indicators as to extent of underground activity are the evidence for pumping and hauling. Unlike spoil heaps, neither can confirm the extent or even the existence of underground activity alone but associated with other evidence such as shafts and spoil heaps they provide useful indicators. The predominance of the horse whim as the favoured hauling device at many of Dartmoor's mines is a further certain guide as to the limited depth of many mines. Horse whims were first introduced in the early 18th century as the foremost hauling device at a time when only the manual windlass was in use; although efficient for mines of limited scale, horse whims operated slowly and by the mid 19th century were considered to be suitable only for mine development, when far more advanced water and steam hoists were available. Nevertheless, water-powered hauling was used infrequently on Dartmoor, which is surprising given the preference for water power for all other aspects of mining in this district, and steam hauling occurred at only two of the mines sampled, though it is known that others existed. The overall impression for the district on this basis is one of shallow mines, small in scale and probably inefficient.

Field evidence for pumping technology in the form of water-powered systems, where supported by documentary dates, can only be identified with certainty from about 1800; although earlier 18th century installations were documented, they were imprecisely provenanced. From 1800 the scale and occurrence of pumping installations increased, although the technology at surface scarcely changed and only about 25% of the total mines recorded have field evidence for pumping. By the 1850s and 60s, several very large waterwheels were installed to power pumping systems. Steam pumping engines were not used on Dartmoor until the 1850s, after which they remained uncommon and only one example has been identified on the high moors. The existence of pumping installations, on whatever scale, cannot always denote a deep and productive mine but often is an indicator of the aspirations of mine adventures to achieve a depth which was not matched by that of the company's pockets; some mines, such as Great Wheal Eleanor, often closed before reaching the full technological potential of their equipment. Large and powerful waterwheels were perceived as an important component of the modernisation needed to restore Dartmoor's mining fortunes and rework former shallow mines to greater depth.

Dartmoor's wet environment had been conducive in creating a water-power culture among its adventurers. This tradition may be traced back to medieval tin extraction when the techniques of diverting and storing the copious supplies provided by the uplands were first developed. In terms of mine promotion, the advantages of water power on Dartmoor were a big attraction from as early as the 1780s, keeping installation and running costs for the prime movers to a minimum, which was essential in the economic equation of marginal mines. The extent of water usage and the ingenuity needed to harness this resource is evident in the field remains of artificial water courses often extending for many kilometres across moorland to serve numerous waterwheels and in some cases multiple mines, where leats were carefully engineered to maximise water use.

Water power was equally favoured for the dressing of ores, once raised to surface. Water-powered stamping mills had been standard technology in the tin industry from at least the 15th century and their effectiveness ensured that the principle of heavy, vertically-reciprocating stamps powered by a rotating overshot or pitchback water wheel remained unchanged until the 20th century. Despite the fundamental changes in the organization of the tin industry and the radical development of underground mining replacing the very different world of the medieval tinners, the stamping mill provides an example of technological continuity, where change was in the nature only of scale and fine tuning as a means of meeting the demands of increased capacity. However, the technology associated with concentrating the stamped tin underwent several evolutionary changes during the study period, designed to increase the efficiency of tin retrieval.

The field evidence reflects the increase in the scale of stamping mills and the developments of the dressing process. Stamping mill remains from the earlier half of the 18th century are rare, though it is possible that some or all of those at Ausewell Mine are of the 1720s. More definite examples survive from the 1790s and the first two decades of the 19th century; this was a period of raised activity which is reflected in the developed layout of the dressing floors and stamping mills with space for four or eight heads of stamps. Unfortunately it is not always possible to date the remains with certainty. Examples are known to have been installed in the 1830s and 40s but a further phase of development is notable between the 1850s and 70s. The field evidence from that period indicates that larger water wheels, increased stamp numbers and advanced dressing techniques, such as circular buddles, were becoming the norm. Strip type settling trenches are also to be observed at a small group of mines.

Over-capacity in the stamping and dressing installations is something of a recurring theme. Stamping mills were often installed long before the mine was developed enough to produce sufficient quantities of ore to warrant one; at mines such as Eylesbarrow, more mills than were likely to be needed were installed, judging by the surface evidence of associated underground activity. It is probable that these mills were considered emblematic by adventurers seeking to inspire confidence in their enterprise, symbolising the consolidation of a mining company's hold on a particular mine and the management's efforts to project their confidence, real or otherwise, that it would be productive. The existence of a stamping mill does not therefore automatically indicate real productivity.

The techniques and machinery associated with the dressing of copper ores, suggest that the quality of much of the material processed was not of a high grade at the Dartmoor mines, although there is no way of knowing from archaeological evidence how much ore of higher grade accompanied it. Modern geological opinion leans towards there having been very few mines which were 'outstanding' in their richness (Durrance & Laming 1982, 126); stamping mills, which survive at several copper mines, were used only for the poorest grades. Buildings to contain crushing machines are well represented in the field and documentary evidence. These devices were specifically developed by Taylor to process 'disseminated' ores of lesser quality. It is at copper mines where some of the largest quantities of dressing waste are to be found on and around Dartmoor, however, if this extent of dressing waste is proportionate to productive mines, it has to be observed that the total where this is the case is very few.

9.2 CONCLUSIONS

This research has proved the value of non-intrusive archaeological investigation as a methodology well suited to the study of upland extractive landscapes. The survey and analysis of a large sample of mining and associated sites, comprising earthworks and ruined structures, supported by evidence from historic maps and documentation, has enabled a plausible chronological and spatial reconstruction of the materiality of mining on Dartmoor, while the human behaviour responsible for its existence, continuity and change has been illuminated through an exploration of wider contexts. The integration of field and documentary evidence into a mutually beneficial partnership has been particularly fruitful.

The study has demonstrated that the mining industry on Dartmoor shared similarities with other mining districts, especially those in Cornwall, in the forms of technology, industrial organization, and in its response to global patterns in the consumption of metals. But for Dartmoor as a discrete mining district, the narrative has to be based on events shaped by the unique qualities of the place and the level of human engagement that those qualities engendered in the people who sought to exploit it for its metals. It was a synergy of environmental and cultural factors that determined the destiny of the Dartmoor mining industry from 1700 to 1914. The combination and extent of natural resources provided by the landscape, set the levels of opportunity and constraint for the adventurers to work within but the level and success of activity was governed by the human response to those resources, driven by external and local human agency providing the dynamics behind most of the choices the adventurers made.

Thus, while the impact of capitalism may be stated to be the foremost of those dynamics, it is also clear that a capitalist model cannot be imposed as a singular theory to explain the changes that may be witnessed through field evidence. The capacity to recognise change that resulted from the unique local context of environment and social antecedent – the influence of the former being a big factor in the latter – has, in this example, proven the effectiveness of a multi-scalar contextual approach.

The above conclusion should not be perceived as an inimitably Dartmoor phenomenon; the methodology is transferable to any other district where mining endured over centuries and where combinations of natural and social agencies can be identified to establish area distinctiveness and provide a backdrop to investigations of the archaeology. Future research elsewhere following this methodology would be fruitful and would undoubtedly produce variability depending on the dynamics which may be established with locality.

At local scale other aspects of the material and documentary evidence for Dartmoor's extractive industries, need to be investigated to build on the achievements of this study. These include the topics of infrastructure, movement of materials and people, housing and settlement, which could add a further social dimension to the research, while silver-lead mines now need to be fully integrated into the general discussion. A high priority must be to explore the surface evidence of some of the important mines that it has not been possible to include in this survey, including Wheal Friendship, Owlacombe, Yeoland and Whiddon. The local scope could also be widened to include the china clay, peat and granite industries, all of which would collectively respond to an examination of the role of capitalism, and provide further insights into Dartmoor's flirtation with 19th-century industrialisation.

It has not been possible to shed much light on the existence or importance of small-scale mining operations within the study period, using the techniques available within this methodology, which has focussed on moderately well-documented mines and their adventurers. Evidence to prove or disprove the existence of low tech 'one man and a boy' type enterprises working outside of, but contemporary with, cost-book and limited liability mine companies would be an important consideration in the capitalist narrative for Dartmoor or indeed any area. Surface extraction techniques such as pit workings may have played a role in smaller-scale 18th and even 19th century mining, as has been proven in the Peak lead mines (Barnatt & Penny 2004, 9). Further examination of this category of tin workings on Dartmoor, through excavation or additional documentary research, could provide dating for a sample of these mines and is one avenue for future consideration.

At a more theoretical level, this study has examined aspects of the genesis and impact of capitalism and a range of contextual considerations, within the limits of only one mining district; ideally the same intellectual exercise should be tried in others. While it is acknowledged that the field methodology adopted here relies on tried and tested techniques already widely in use on mining landscapes, it is to be hoped that the results of more investigations of mining landscapes in the United Kingdom could be the subject of theoretically informed analyses of the type that have proved so beneficial in the interpretation of field remains achieved by this study.

APPENDIX A

Alphabetical list of documented mines within Dartmoor National Park and environs, following step-one desktop survey

A = Mine number; B = site number; P = primary site reference

Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Adam, Wheal	358	Wheal Exmouth (P)	Hennock	Lysons 1822, 275;		
Adams	261	Wheal Exmouth (P)	Hennock	Collins 1912, 399; Hamilton Jenkin 1981, 151; Burt et al 1984, 1		
Adventure	436	Kitts, Reform	Lydford	Dines 1988, xxxi	100	
Agnes, Devon Wheal	513	East Vitifer (P)	North Bovey	Broughton 198/9 16-18, Fig 2;	63	
Ailsborough	253	Eylesbarrow (P), Dartmoor Consolidated, Dartmoor Consols, Wheal Ruth,	Sheepstor	Lysons 1822, Cook et al 1974, 161-214; Newman 1999, 105-48;	1	
Albert, Wheal	106	Whiteworks, Wheal Florence	Plympton	Collins 1912, 412-3; Dines 1956, 687; Hamilton Jenkin 1974, 129; Hamilton Jenkin 1974, 18	2	p
Albion	221	Atlas (P), South Devon Iron & General Mining Co	Ilsington	Collins 1912, 406; Dines 1956, 732; Burt et al 1984, 1	3	
Aller	262	Birch Aller	Christow	Collins 1912, 403; Hamilton Jenkin 1981, 163; Burt et al 1984, 1; Dines 1988, xxxvii		
Alliance	542	Roughtor	Sheepstor	English 1826, 3	108	P
Amery	264		Christow	Collins 1912, 403; Burt et al 1984, 2		
Ammicombe, Wheal	438	Rattlebrook, North Dartmoor Consols, Duke of Wellington Consols	FoD	Dines 1988, xxxi	4	
Anderton United	154	Anderton, Old Anderton, New Anderton, Rix Hill, Tavistock United	Whitchurch	Collins 1912, 403;Burt et al 1984, 2	95	P
Anderton, New	151	Rix Hill, Wheal Ash, Tavistock Consols, Old Anderton, Anderton United (P)	Whitchurch	Dines 1956, 692; Hamilton Jenkin 1974, 66	95	
Anderton, Old	153	Rix Hill, Anderton, New Anderton, Tavistock Consols, Wheal Ash, Anderton United (P)	Whitchurch	Dines 1956, 692; Hamilton Jenkin 1974, 66	95	
Anderton, Wheal	149	Rixhill, New Anderton, Old Anderton, Wheal Ash, Tavistock Consols, Anderton United	Whitchurch	Collins 1912, 403; Dines 1956, 692; Harris 1968, 56; Hamilton Jenkin 1974, 66	95	
Ann Wheal	187	South Wheal Freindship, South Devon United	Peter Tavy	Dines 1956, 707; Le Messurier 1966, 65; Hamilton Jenkin 1981, 42		
Anna Maria	417	Lawrence, Dunsford Mine	Dunsford	Dines 1956, 742; Dines 1988 xxxvi		
Arthur, Prince Consols	124	Old Wheal Betsy, Wheal Betsy (P)	Mary Tavy	Hamilton Jenkin 1981, 32; Burt et al 1984, 92	86	
Arundell United	74	Devon New Copper, Druid, New Victoria, Ashburton Tin & Copper, East Dartmoor Tin & Copper	Ashburton	Collins 1912, 608; Dines 1956, 636-7; Hamilton Jenkin 1981, 111-16; Nance & Nance 1996, 109-22; Von Arx 1995; Newman 2003 , 173-218	5	P
Ashburton Consols	267	Ashburton United, Owlacombe(P), West Beam, Stormsdown	Ashburton	Collins 1912, 405; Rowe 1896, 269	98	
Ashburton Tin and Copper	77	Druid, Arundell, Devon New Copper, New Victoria, East Dartmoor Tin and Copper	Ashburton	Collins 1912, 608; Dines 1956, 636-7; Von Arx 1995; Nance & Nance 1996, 109-22; Newman 2003 , 173-218; Hamilton Jenkin 1981, 111-16	5	
Ashburton United	298	Owlacombe(P), Ashburton Consols, Stormsdown, West Beam	Ashburton	Burt et al 1984, 3	98	
Ashburton, East	268	Wheal Lemon	Ashburton	Collins 1912, 406; Hamilton Jenkin 1981, 124; Burt et al 1984, 3		
Ashburton, West	269		Ashburton	Rowe 1896, 269; Collins 1912, 406; Burt et al 1984, 3;		
Atlas	52	Albion	Ilsington	Rowe 1896, 269; MacAlister 1912, 76; Collins 1912, 406; Dines 1956, 732; Burt et al 1984,3	3	P
Augusta Consols	510		Bridestow	Bl, Bridestow		
Ausewell	14	Hazel Copper Mine, East Wheal Hazel, Wheal Hazel Mining Co	Ashburton	Brooke 2001, 46; Phillpotts 2003; Newman 2004;	6	P
Avon Consols	66	Huntington (P), Devon Wheal Vor, New Huntingdon, Devon Consols Tin	Dean Prior	Brooke 1980, 74-6; Dines, 1956, 729-30; Hamilton Jenkin 1981, 85-86; Greeves 2001, 8-10	7	

Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Bachelors Hall	82	Batchelor's Hall	FoD	Lysons 1822, 273; Dines 1956, 730; Le Messurier 1967, 50; Hamilton Jenkin 1974, 94-5; Dickinson 1975; Atkinson et al 1978, 47; Greeves 1997a, 7; Gray 2000, 55	8	P
Bagtor	67	Haytor Consols(P), Great Central, Crownley, Hemsworthy, Cranstoun	Ilsington	Collins 1912, 406; Dines 1956, 732; Atkinson et al 1978, 12; Hamilton Jenkin 1981, 132-5; Burt et al 1984, 4; Barton 1968, 189	9	
Bal	379		Walkhampton	Hemery 1983, 146	10	P
Barracott	210		North Bovey	Dines 1956, 724, Atkinson et al 1978, 47		
Battishill Down	200	(?)Wheal Mary	Bridestowe	Dines 1956, 711		
Beam	270	Ashburton United, Owlacombe(P), Stormsdown, Wheal Beam	Ashburton	Collins 1912, 412; Hamilton Jenkin 1981, 118; Burt et al 1984, 6	109	
Beam, West	271	Ashburton United, Owlacombe(P), Stormsdown	Ashburton	Collins 1912, 412, Hamilton Jenkin 1981, 119; Burt et al 1984, 6	109	P
Beardown	11	Wheal Virgin	FoD	Dickinson 1975; Greeves 2002a	11	P
Bedford Consols	299		Tavistock Hamlets	Rowe 1896, 270; Burt et al 1984, 7		
Bedford United	139		Tavistock Hamlets	Rowe 1896, 270; Collins 1912, 412; Dines 1956, 664-6; Hamilton Jenkin 1974, 18, 29; Burt et al 1984, 6, 7-10		
Bedford, Wheal	356	Bedford United, Bedford Consols	Tavistock Hamlets	Lysons 1822, 275; Barton 1968 173		
Belstone Consols	223	Mid Devon, Copper Hill, Taw River, Sticklepath Hill Mine, Ivy Tor	Belstone	Dines 1956, 752; Hamilton Jenkin 1981, 68; Harris 1968, 62; Barton 1968, 189; Barton 1970, 43; Burt et al 1984, 10-11	83	P
Bennah	420	Christow Silver-Lead	Christow	Dines 1956, 744; Dines 1988, xxxvii		
Bertha Consols	272	?Lady Bertha	Buck Mon	Collins 1912, 414; Burt et al 1984, 11-12		
Bertha, East Lady	301	East Wheal Bertha	Buck Mon	Dines 1956, 701; Burt et al 1984, 12;	80	P
Bertha, East Wheal	273	East Lady Bertha (P)	Buck Mon	Rowe 1896, 269; Collins 1912, 415; Burt et al 1984, Burt et al 1984, 12	80	
Bertha, Lady	302		Buck Mon	Dines 1956, 701; Hamilton Jenkin 1974, 50-5; Burt et al 1984, 12-13; Richardson 1992, 129;	71	P
Bertha, Lady, United	499	Lady Bertha (P)	Buck Mon	BI, Buck Mon	71	
Betsy, North Wheal	193		Mary Tavy	Collins 1912, 415; Dines 1956, 709		
Betsy, Old Wheal	380	Prince Arthur Consols	Mary Tavy	Collins 1912,415;	86	
Betsy, South Wheal	275		Mary Tavy	Rowe 1896, 270; Collins 1912, 415; Burt et al 1984, 14;		
Betsy, Wheal	33	Prince Arthur Consols, Blackdown	Mary Tavy	Watson 1843, 55; Collins 1912, 415; MacAlister 1912, 79; Dines 1956, 709; Le Messurier 1966, 65; Le Messurier 1967, 50; Harris 1968, 65; Burt 1977, 25; Hamilton Jenkin 1981, 29-32; Burt et al 1984, 13-14;	86	P
Birch Aller	276	Birch Ellers, Aller	Bridford	Collins 1912, 416; Hamilton Jenkin 1981, 166; Burt et al 1984, 14; Dines 1988, xxxvii		
Birch Tor	203	Birch Tor & Vitifer (P), Birch Tor Consols, New Birch Tor etc	North Bovey	Collins 1912, 66, 416; Dines 1956, 720-4; Broughton 1968/9, 7; Hamilton Jenkin 1974, 101-7; Newman 2002, 28-36	12	
Birch Tor and Vitifer	202	Birch Tor, New Birch Tor etc, Birch Tor Consols, Vitifer	North Bovey	Collins 1912, 66, 416; Dines 1956, 720-4; Harris 1968, 46-50; Broughton 1968/9, 7; Broughton 1971; Hamilton Jenkin 1974, 101-7; Atkinson et al 1978, 12; Burt et al 1984, 14-16; Greeves 1986 21-44; Newman 2002, 28-36	12	P
Birch Tor Consols	412	Birch Tor, Birch Tor and Vitifer(P)	North Bovey	Dines 1956, 720	12	
Birch Tor, East	46	East Burch Tor, Headland Mine, Devon Great Tincroft, New East Birch Tor, East Birch Tor Tin,	North Bovey	Rowe 1896, 269; Dines 1956, 723; Broughton 1968/9; Hamilton Jenkin 1974, 175; Burt et al 1984, 16; Newman 2002, 45-9	24	P
Black Down	468	Wheal Betsy(P), North Wheal Friendship, Blackdown	(?) Mary Tavy	Brooke 2001, 10; Hamilton Jenkin 1981, 41	86	
Blackpool, Wheal	58	(?)Knight of Dart	Buckfastleigh	Hamilton Jenkin 1981, 104; Dines 1988, xxxvi	13	P
Boringdon Consols	103	Borington Park, East Boringdon	Plympton	Collins 1912, 418; Dines 1956, 686; Hamilton Jenkin 1974, 120-2; Burt et al 1984, 16-17		
Boringdon Park	20	Boringdon Consols	Plympton	Collins 1912, 418; Dines 1956, 686; Hamilton Jenkin 1974, 120-2; Burt et al 1984, 17		
Boringdon, East	108	Boringdon Consols	Plympton	Collins 1912, 418; Dines 1956, 686; Hamilton Jenkin 1974, 120-2; Burt et al 1984, 17		
Boro Wood	13		Ashburton	Newman 2003, 183	14	P
Bottle Hill	21	Bottlehill, Wheal Mace	Plympton	Lysons 1822, 273; Rowe 1896, 269; Collins 1912, 422; Dines 1956, 687; Barton 1968, 172; Harris 1968, 55; Hamilton Jenkin 1974, 125-6; Burt et al 1984, 17-18;		

Appendix (cont)

Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Bottle Hill, East	278	Wheal Woolcombe	Plympton	Collins 1912, 422; Hamilton Jenkin 1974, 126,129; Burt et al 1984, 18; Dines 1988, xxviii		
Boucher	156		Holne	DRO 1311/M/deeds/4/6 (primary source)		
Bowden Common	279	Bowden Hill	Brentor	Collins 1912 422; Dines 1956, 726; Hamilton Jenkin 1981, 17; Burt et al 1984, 18-19		
Bowden Hill	414		Bovey Tracey	Dines 1956, 726		
Bowden Hill (2)	218	Bowdon Common	Brentor	Collins 1912 422; Dines 1956, 726; Atkinson et al 1978, 47; Hamilton Jenkin 1981, 17		
Bowdley Consols	520	West Ashburton, East Hazel	Ashburton	Hamilton Jenkin 1981, 117		
Bradford Pool	447	Wheal St Ann	Drerwsteignton	Dines 1988, xxxix; Costello 1981, 59-77		
Brent	22		South Brent	Bl, South Brent		
Brentor	528		Brentor	Bl, Brentor		
Bridford Consols	280		Bridford	Collins 1912, 423; Hamilton Jenkin 1981, 164		
Brimpts	4	Devon Tin, Duke of Cornwall Consolidated, Brempts; Brent's	FoD	Lysons 1822, 273;Collins 1912, 369; Dines 1956, 728; Hamilton Jenkin 1974,95-6; Le Messurier 1967, 50; Dickinson 1977; Bird & Hirst 1996; Greeves 1997a, 7	15	P
Brookwood	44	South Devon United, Macclesfield, Buckfasleigh Manor	Buckfastleigh	Rowe 1896, 269; MacAlister 1912, 77; Collins 1912, 425,477; Dines 1956, 738-9; Barton 1968,186; Harris 1968, 61; Hamilton Jenkin 1981, 92-100; Burt et al 1984, 22; Dines 1988, xxxvi; Hall 2000, 126-30; Levy 2005; Newman 2005; Newman 2007	16	P
Brookwood, East	25	Wrey Consols	Holne	Hamilton Jenkin 1981, 98-9;Burt et al 1984, 22	17	P
Brookwood, New	68	Newbrook Wood, Burchetts (Wood)	Buckfastleigh	Dines 1956, 738-9; Hamilton Jenkin 1981, 98; Burt et al 1984, 22; Dines 1988, xxxvi	18	P
Brothers, Wheal	325	Owlacombe(P), Ashburton United, West Beam, Wheal Union, Stormsdown	Ashburton	Dines 1956, 735; Hamilton Jenkin 1981, 120;	98	
Buckfastleigh Manor	63	Brookwood, Macclesfield, Emma, South Devon United	Buckfastleigh	Collins 1912, 427; Brewer 1988, 7-10; Brooke 2001, 46; Newman 2005	16	
Buckfastleigh Tin	71	Dean Prior, 'Tin Mines'	Buckfastleigh	Collins 1912, 427;		
Buddleybeer	467	Budlake, Wheal Jewell (P), Budlar	(?) Mary Tavy	Brooke 2001, 10	85	
Budlake	61	Wheal Jewell (P), Budlar	Mary Tavy	Donn 1765	85	
Budlar, Wheal	516	Buddleybeer, Budlake, Wheal Jewell(P)	Mary Tavy	Dickinson 1977		
Buller and Bertha, Wheal	372		Buck Mon	Rowe 1896, 269; Dines, 1956, 701, Hamilton Jenkin 1974, 49-50		
Buller, Wheal (Devon)	177	Devon Wheal Buller, South Roborough Down	Buck Mon	Rowe 1896, 269; Dines 1956, 702; Burt et al 1984, 23; Burt et al 1984, 37; Barton 1968, 98		
Burn, Wheal	517		Mary Tavy	Bl, Mary Tavy		
Burn, Wheal	370		(?) Tavistock	Lysons 1822, 275		
Burra Burra	381	Devon Burra Burra (P), Wheal Gatepost	Whitchurch	Hunt 1865, 33; Collins 1912, 430; Barton 1968, 107;	94	
Burra Burra, Devon	146	Wheal Gatepost, Burra Burra	Whitchurch	Hunt 1865, 33; Collins 1912, 467; Dines 1956, 691; Hamilton Jenkin 1974, 69-70; Burt et al 1984, 37-8; Barton 1968, 107;	94	P
Bush Down	205		Chagford	Dines 1956, 723; Atkinson et al 1978, 16; Newman 2002, 45;	77	P
Buttspill	411	Tamar Valley	Bere Ferrers	Dines 1956, 683		
Callacombe	465		Lamerton	Rowe 1896, 270		
Calmady, Wheal	170		Bridestow	Dickinson 1975, 102-8		
Cann	23		Plympton	Hamilton Jenkin 1974, 120		
Caroline, Wheal	83		FoD	Newman 2002, 41-3	79	P
Carpenter, Wheal	366		(?)Whitchurch	Lysons 1822, 275		
Castle, Wheal	437	Kitts, Reform	?Lydford	Dines 1988, xxxi	100	
Castle, Wheal	234	Halstock	Okehampton	Dines 1956, 753; Hamilton Jenkin 1982, 62	19	P
Chagford Consols	24		Chagford	Burt et al 1984, 24		
Champion, Wheal	492	Roborough (Down) Mines	Buck Mon	Greeves & Newman 1994, 216		
Chance, Wheal	6	Wheal Chance and Nuns	Walkhampton	Newman 1987, 8-10	20	P
Charlotte, Wheal	365		(?) Buckland Monachorum	Lysons 1822, 275; Barton 1968, 170; Greeves & Newman 1994, 215		
Christow (Silver-lead)	421	Bennah	Christow	Dines 1956, 744		

Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Collier, Wheal	483	Huckworthy	Sampford Spiney	Hamilton Jenkin 1974, 81		
Combe	443	Runnaford Combe(P)	Buckfastleigh	Dines 1988, xxxvii	21	
Combeshead	527	Eylesbarrow	Sheepstor	Greeves 1969, 197-201	102	P
Concord	336		Whitchurch	Lysons 1822, 273;		
Concord, East	337		Whitchurch	Lysons 1822, 273		
Copper Bottom, New	502		Bridestow	Bl, Bridestowe		
Copper Hill (Great)	224	Mid Devon, Taw River, Sticklepath Hill, Belstone Consols	Belstone	Dines 1956, 522; Hamilton Jenkin 1981, 68	83	
Cornwall Consolidated, Duke of	257	Brimpts(P), Devon Tin	FoD	Hamilton Jenkin 1974, 95-7; Bird & Hirst 1996;	15	
Crakern Beam	364	Creakham, Crinken, Wheal Franco	(?)Buck Mon	Lysons 1822, 275		
Crane Lake	254	Wheal Katherine(P)	FoD	Cook et al 1974, 161-214; Newman 1999, 105-48;	41	
Crapstone Consols	171		(?)Walkhampton	Greeves and Newman 1994, 215		
Crebor, East Wheal	147	East Crowndale, South Crowndale, West Rixhill	Whitchurch	Collins 1912, 459; Dines 1956, 691; Hamilton Jenkin 1974, 65-6; Burt et al 1984, 33		
Crelake	145		Whitchurch	Rowe 1896, 270; Collins 1912, 461; Dines 1956, 690; Hamilton Jenkin 1974, 67-9; Burt et al 1984, 34;		
Crown Hill	332		? Sheepstor	Lysons 1822, 273		
Crowndale, East	148	East Crebor, East Crowndale	Whitchurch	Lysons 1822, 273; Collins 1912, 465; Dines 1956, 692; Hamilton Jenkin 1974, 65; Burt et al 1984, 35		
Crowndale, South	240	West Rix Hill	Whitchurch	Collins 1912, 465; Dines 1956, 692; Hamilton Jenkin 1974, 66		
Crowndale, Wheal	239		Tavistock	Lysons 1822, 273; Collins 1912, 464; Dines 1956, 673; Barton 1968, 169; Burt 1977; Hamilton Jenkin 1974, 64-5; Burt et al 1984, 34-5;		
Crownley	137	Haytor Consols(P), Bagtor, Great Central, Cranstoun	Ilsington	Hamilton Jenkin 1981, 132-4	9	
Cumpston, Wheal	80	Dartmoor Consols, Dartmoor United	FoD	Watson 1843, 56; Collins 1912, 467; Dines 1956, 728; Greeves 1978, 161-71	22	P
Curbeam	486	Kerbeam, North Dartmoor, Cur Beams, Curr Beam	FoD	Polwhele 1797-1806, 56; Greeves 1997a 7	91	P
Dart United	391	Wheal Dart(?)	Ashburton	Rowe 1896, 269; Collins 1912, 467		
Dartmoor (Tin) Mines	547	Vitifer	FoD			
Dartmoor Consolidated	251	Ailsborough, Eylesbarrow, Dartmoor Consols, Wheal Ruth	Sheepstor	English 1827,17; Hamilton Jenkin 1974, 87; Cook et al 1974, 161-214; Newman 1999, 105-48	1	
Dartmoor Consols	250	Ailsborough, Eylesbarrow, Dartmoor Consolidated, Wheal Ruth	Sheepstor	Cook et al 1974, 161-214; Newman 1999, 105-48	1	
Dartmoor Consols, North	48	(?)Rattlebrook, (?)Wheal Frederick, (?)Mary Emma, North Dartmoor Tin Mine, Wheal Ammicombe, Rattlebrook, Curbeam	Bridestowe	Bradford Barton, 1967; Burt et al 1984, 35		
Dartmoor Forest	247	Huntingdon(P), Devon Wheal Vor, Devon Consols Tin, Avon Consols, New Huntingdon, East Wheal Rose	Dean Prior	Brooke 1980, 74-6; Greeves 2001, 8-10	23	
Dartmoor United	259	Deby Hole, Gobbet, Wheal Cumpston, Swinecombe Vale	FoD	Hamilton Jenkin 1974, 98		
Dean Prior	182	Buckfastleigh	Dean Prior	Hamilton Jenkin 1981, 86; Burt et al 1984, 35-6		
Dean Prior and Buckfastleigh	444	Buckfastleigh Tin Mine	Buckfastleigh	Dines 1956, xxxvii		
Deancombe	87	Dean Combe	Sheepstor	Dickinson 1975, 102-8		
Deby Hole	81	Dartmoor Consols, Dartmoor United	FoD	Watson 1843,56; Collins 1912, 467; Dines1956, 728; Greeves 1978; Hamilton Jenkin 1981,86		
Devil's Kitchen	335		Tavistock	Lysons 1822, 273		
Devon and Courtenay Consols	160	Birchwood	Whitchurch	Rowe 1896, 269; Collins 1912, 468; Dines 1956, 693; Hamilton jenkin 1974 64; Burt et al 1984,36-7;		
Devon Consols Tin	116	Huntingdon(P), Avon Consols, Devon Wheal Vor, New Huntingdon, East Wheal Rose, Dartmoor Forest	Dean Prior	Hamilton Jenkin 1981, 86; Burt et al 1984, 38	23	
Devon Consols, East	305			Rowe 1896, 270; Burt et al 1984, 38		

Appendix (cont)

Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Devon Copper	306	Okehampton Wheal Maria	Okehampton	Hamilton Jenkin 1981, 59; Burt et al 1984, 38; Dines 1988, xxxix;	68	P
Devon New Copper Mining Co.	75	Druid, Arundell, New Victoria, Ashburton Tin & Copper, East Dartmoor Tin & Copper	Ashburton	Rowe 1896, 269; Hamilton Jenkin 1981, 114; Burt et al 1984, 39; Newman 2003 , 173-218;	5	
Devon Tin	220	Brimpts(P), Duke of Cornwall Consolidated	FoD	Collins 1912, 469; Dines 1956, 728; Hamilton Jenkin 1974, 97; Atkinson et al 1978, 47; Burt et al 1984, 44; Bird & Hurst 1997	15	
Devon United	188	North Devon United, South Devon United, Wheal Ann, South Wheal Friendship, East Wheal Freindship	Peter Tavy	Collins 1912, 469; Dines 1956, 708-9; Le Messurier 1966, 67; Harris 1968, 56; Hamilton Jenkin 1981, 44; Burt et al 1984, 44-5; Richardson 1992, 53-60	106	P
Devon United Copper, South	30	Brookwood(P), Wheal Emma(P), Macclesfield, Buckfastleigh Manor	Buckfastleigh	Dines 1956, 739; Hamilton Jenkin 1981, 92-100; Burt et al 1984, 45; Newman 2005	16	
Devon United, Central	192	Devon United(P)	Peter Tavy	Collins 1912, 469; Dines 1956, 708; Hamilton Jenkin 1981, 45; Richardson 1992, 53-60	106	
Devon United, North	189	Devon United(P)	Peter Tavy	Collins 1912, 469; Dines 1956, 708-9; Hamilton Jenkin 1981, 44; Richardson 1992, 53-60	106	
Devon United, South	190	Devon United(P), South Wheal Freindship	Peter Tavy	Collins 1912, 469; Dines 1956, 708-9; Barton 1968, 188; Hamilton Jenkin 1981, 44; Richardson 1992, 53-60	106	
Devon, New Wheal	392		Ashburton	Collins 1912, 468		
Ding Dong	141	Bedford United	Tavistock Hamlets	Lysons 1822, 273; Dines 1956, 667		
Dippertown	462		Marystow	Rowe 1896, 270		
Dolly, Wheal	548		FoD	Burnard 1891, 97		
Dorothy, Wheal	248		FoD	Burnard 1891, 111-12; Crossing 1909, Greeves 2002, 8-10;	78	P
Dreamers Delight	88			Dickinson 1975, 102-8		
Druid	12	Arundell United Copper(P), New Victoria Co Ltd, Devon New Copper Mining Co Ltd, Ashburton Tin and Copper Mining Co Ltd, East Dartmoor Tin and Copper Mining Co Ltd	Ashburton	Collins 1912, 608; Dines 1956, 636-7; Burt et al 1984,47; Dines 1988, xxxv; Von Arx 1995; Nance & Nance 1996, 109-22; Newman 2003 , 173-218 Hamilton Jenkin 1981, 111-16	5	
Duchy, Devon Wheal	511		Whitchurch			
Duchy, Wheal	376		FoD		76	P
Dunsford	419	Anna Maria	Dunsford	Dines 1956, 742		
East Dartmoor Tin and Copper Mining Co.	76	Druid, Arundell(P), Devon New Copper, New Victoria, Ashburton Tin & Copper,	Ashburton	Collins 1912, 608; Dines 1956, 636-7; Von Arx 1995; Nance & Nance 1996, 109-22; Newman 2003 , 173-218 Hamilton Jenkin 1981, 111-16	5	
Eleanor, Great Wheal	167		North Bovey	MacAlister 1912, 79; Collins 1912, 475; Dines 1956, 724; Broughton 1968-9, 17-19; Broughton 1971; Hamilton Jenkin 1974, 107-8; Atkinson et al 1978, 31; Burt et al 1984,48-9;	25	P
Eliza, Wheal	515	Henscott Consols	Mary Tavy			
Elizabeth, Devon Great	16	(?) Wheal Elizabeth	Widecombe	Hamilton Jenkin 1981, 109-10; Burt et al 1984, 42; Dines 1988, xxxvi	26	P
Elizabeth, Wheal	476	(?) Devon Great Elizabeth	Buckfastleigh	Barton 1968, 98	26	
Ellen, (Devon) Great Wheal	284	Whiddon(P), Bowdley Consols, Brownshill	Ashburton	Collins 1912, 476; Hamilton Jenkin 1981, 117; Burt et al 1984, 42; Rowe 1896, 269	27	
Emily, Wheal	229	Ramsley(P), Fursdon, South Zeal Consols	South Tawton	Dines 1956, 753; Hamilton Jenkin 1981, 74; Burt et al 1984, 49	28	
Emma, New Wheal	504	Wheal Emma (P)	Buckfastleigh			
Emma, Wheal	45	South Devon United, Buckfastleigh Manor, Macclesfield	Buckfastleigh	MacAlister 1912, 77; Collins 1912, 477; Dines 1956, 738-9; Dickinson 1977; Hamilton Jenkin 1981, 92-100; Burt et al 1984,49-50; Brewer 1988, 7-10; Dines 1988, xxxvi; Hall 2000, 126-30; Levy 2005; Newman 2005;	16	P
Exmouth, North	308		Christow	Rowe 1896, 269; Burt et al 1984, 52;		
Exmouth, South (Wheal)	286	Wheal Hennock	Christow	Collins 1912, 478; Hamilton Jenkin 1981, 148; Burt et al 1984, 52; Dines 1988, xxxvii		
Exmouth, Wheal	242	Wheal Adams	Christow	Rowe 1896, 269; Collins 1912, 477; Dines 1956, 745; Hamilton Jenkin 1981, 153; Burt et al 1984, 51; Hall 2000, 119-25		
Eylesbarrow	8	1814 (Ailsborough); 1836 (Dartmoor Consolidated); 1845 (Dartmoor Consols); 1849 (Aylesborough); 1851 (Wheal Ruth)	Sheepstor	Dines 1956, 56, 731; Le Messurier 1967, 50; Harris 1968, 45-6; Cook et all 1974, 161-214; Hamilton Jenkin 1974, 87-90; Dickinson 1977; Atkinson et al 1978, 18-19; Greeves 1986, 3; Neill 1991, 3-6; Newman 1999, 105-48;	1	P

Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Fanny, Wheal	491		Meavy			
Fanny, Wheal	428	Leawood	Bridestow	Dines 1956, 751; Broughton 1971;		
Florence	199		Lydford	Dines 1956, 711; Burt et al 1984, 52		
Florence, Wheal	105	Whiteworks, Wheal Albert (P)	Sparkwell	Dines 1956, 687; Hamilton Jenkin 1974, 129	2	
Forest	131	Homerton, Okement Consols	Okehampton Hamlets	Dines 1956, 751-2; Hamilton Jenkin 1981, 58; Burt et al 1984, 54		P
Forrest Hill	470	Furzehill Wood	Horrabridge	Brooke 2001, 11	32	
Fortune, Wheal	50	Merrifield Bridge, Merrivale Bridge, Morefield Bridge	Whitchurch	Greeves 1976, 3-5, 11; Newman 1993, 5-8	29	P
Fortune, Wheal (3)	446	Gooseford, Throwleigh	South Zeal	Dines 1956, xxxviii; Broughton 1971;		
Foxhole	127	Wheal Frederick	FoD	Collin 1912, 483; Dines 1956, 711; Atkinson et al 1978, 47	31	
Frances, Devon Wheal	136	Yarner(P), Yarrow	Bovey Tracey	Collins 1912, 613; Dines 1956, 732; Barton 1968, 98; Hamilton Jenkin 1981, 139; Burt et al 1984,39;	30	
Franco, Wheal	84	Wheal Franco Consols, Wheal Robert, Crackern Beam	Horrabridge	Watson 1843, 50; Rowe 1896, 269; Collins 1912, 484; Dines 1956, 698-699; Harris 1968, 60; Hamilton Jenkin 1974, 82-3; Burt et al 1984, 55;		
Frank Mills	289	Teign Valley Lead	Christow	Rowe 1896, 269; Collins 1912, 484; Hamilton Jenkin 1981, 157; Burt et al 1984, 55-6		
Frederick, Wheal	49	Foxhole, Duke of Wellington Consols, Great Duke of Wellington, Rattlebrook, DoeTor, Curbeam	FoD	Rowe 1896, 270; Burt et al 1984, 56; Greeves 2003, 23	31	P
Freindship, East Wheal	185	Devon United	Peter Tavy	Collins 1912, 486; Dines 1956, 708; Barton 1968, 172; Hamilton Jenkin 1981, 44; Burt et al 1984, 59;		
Freindship, North Wheal	541	Wheal Saturday, Hillbridge Consols	Mary Tavy	Hamilton Jenkin 1981, 43	107	P
Freindship, South Wheal	186	Wheal Ann, South Devon United (P)	Peter Tavy	Collins 1912, 485; Dines 1956, 707-8; Barton 1968, 173; Hamilton Jenkin 1981, 42		
Freindship, West Wheal	183		Mary Tavy	Dines 1956, 704; Hamilton Jenkin 1981, 39-40		
Freindship, Wheal	184	Devon Freindship, Huel Freindship	Mary Tavy	Maton 1797, 297; Lysons 1822, 273; Watson 1843, 55; Rowe 1896, 270; MacAlister 1912, 78; Collins 1912, 267, 485; Dines 1956, 705-7;Le Messurier 1966, 65; Le Messurier 1967, 50; Raistrick 1967, 23; Harris 1968, 58-9; Burt 1977; Hamilton Jenkin 1981, 33-8; Burt et al 1984, 56-9	105	P
Friendship, East Wheal (Buckfastleigh)	263		Buckfastleigh	Collins 1912, 403		
Friendship, North	191	Wheal Betsy(P), Prince Arthur Consols, Black Down	Mary Tavy	Rowe 1896, 270; Collins 1912, 415; Dines 1956, 709; Hamilton Jenkin 1981, 29-32; Burt et al 1984, 59-60	86	
Fursdon (Manor)	230	Ramsley, Wheal Emily, South Zeal Consols, Fursdon Great Consolidated	South Tawton	Rowe 1896, 269; Dines 1956, 753; Broughton 1971; Hamilton Jenkin 1981, 73; Burt et al 1984, 60-1;	28	
Furze Hill West	309		Horrabridge	Burt et al 1984, 62		
Furzehill	95	Furzehill Wood	Horrabridge/Walkhampton	Rowe 1896, 269; Collins 1912, 487; Dines 1956, 699-700; Hamilton Jenkin 1974, 83-5; Dickinson 1977; Burt et al 1984, 61-2;	32	P
Furzehill	339		Buck Mon	Lysons 1822, 273		
Gatepost, Wheal	487	Devon Burra Burra (P)	Whitchurch	Hunt 1865, 33; Hamilton Jenkin 1974, 69-75;	94	
Gem	291	(?)Little Gem, West Sortridge Consols	Whitchurch	Collins 1912, 489; Burt et al 1984, 65	74	
Gem, Little	244	West Sortridge Consols, Walkham Valley	Whitchurch	Dines 1956, 695; Barton 1968, 107	74	P
George, (East) Wheal	241	Wheal George, Huckworthy	Walkhampton	Dines 1956, 698; Hamilton Jenkin 1974, 81-2; Burt et al 1984, 65	69	P
George, Wheal	440	Wheal Ammicombe	FoD	Dines 1988, xxxi		
Georgina, Wheal	350		(?) Tavistock	Lysons 1822, 274		
Gibbet (Hill)	201		Mary Tavy	Collins 1912, 490; Dines 1956; 710	96	P
Gobbett	79	Dartmoor Consols, Dartmoor United, Swincombe Vale, Gobbets	FoD	Lysons 1822, 273; Watson 1843, 56; Collins 1912, 467; Dines 1956, 728; Le Messurier1967, 50; Hamilton Jenkin 1974, 98-9; Atkinson et al 1978, 20; Burt et al 1984,65; Greeves 1986, 16; Greeves 2006, 12	33	P
Gods Hall	329		Walkhampton	Lysons 1822, 273		

Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Golden Dagger	17		Manaton	Collins 1912, 492; Dines 1956, 723; Le Messurier 1967, 51; Hamilton Jenkin 1974, 106; Atkinson et al 1978, 22; Burt et al 1984, 65-7; Greeves 1986, 45-80; Newman 2002, 36-40	34	P
Good Luck	474	Wheal Chance	Walkhampton	SYM 01-04-1793	20	
Gooseford	445	Wheal Fortune, Throwleigh	South Tawton	Dines 1956, xxxviii; Hamilton Jenkin 1981, 76-8		
Great Central	429	Bagtor, Haytor Consols(P), Smith's Wood	Ilsington	Broughton 1971;	9	
Great Rock	219		Hennock	Dines 1956, 727; Atkinson et al 1978, 24-30; Hamilton Jenkin 1981, 151; Burt et al 1984, 67-8		
Great Tincroft, Devon	266	East Birch Tor,Headland	North Bovey	Collins 1912, 405	24	
Grenofen, Wheal	342		Whitchurch	Lysons 1822, 273; Greeves & Newman 1994, 216		
Grimstone	340		Sampford Spiney	Lysons 1822, 273		
Halstock	431	Wheal Castle(P)	Okehampton	Dines 1956, 753	19	
Harehill Plantation	424		Doddiscomsleigh	Dines 1956, 748		
Harmony, Wheal	545	Wilkins, Roundhill	FoD	Greeves 1997a, 7		
Harriot Sophia, Wheal	484		Cornwood	BI, Cornwood		
Hawkmoor	213		Bovey Tracey	Dines 1956, 726; Atkinson et al 1978, 31; Burt et al 1984, 70		
Haytor Consols	72	Bagtor, Hemsworthy, Crownley, Great Central, Cranstoun	Ilsington	Collins 1912, 506; Dines 1956, 731-3; Broughton 1971; Hamilton Jenkin 1981, 132-5; Burt et al 1984, 71;	9	P
Haytor Iron	28		Ilsington	Collins 1912, 506; Dines 1956 732; Harris 1968, 68; Hamilton Jenkin 1981, 136; Burt et al 1984, 70-1;		
Hazel, East	310	Auswell(P), Wheal Hazel	Ashburton	Burt et al 1984, 72	6	
Hazel, Wheal	292	East Wheal Hazel, Ausewell(P)	Ashburton	Collins 1912, 507; Hamilton Jenkin 1981, 108; Burt et al 1984, 71; Newman 2004	6	
Headland Mine	204	East Birch Tor(P)	North Bovey	Dines 1956, 723	24	
Heckwood	172		Walkhampton	BI, Sampford Spiney		
Hemerdon Consols	109		Plympton	Dines 1956, 688; Harris 1968, 55; Hamilton Jenkin 1974, 125; Burt et al 1984, 72		
Hemsworthy	18	Wheal Water, Haytor Consols(P), Bagtor	Ilsington	Dines 1956, 731; Atkinson et al 1978, 48; Hamilton Jenkin 1981, 132	9	
Hennock	293	Hennock & Christow	Chudleigh	Collins 1912, 507; Hamilton Jenkin 1981, 146; Dines 1988, xxxvii		
Hennock, Iron and Tin	456	Great Rock	Hennock	Hamilton Jenkin 1981, 150-1		
Henroost	113	Hensroost, Hexworthy(P), Holme Moor, Wheal Unity, Wheal Princetown	FoD	Dines 1956, 729; Le Messurier 1966, 65; Harris 1968, 50-2; Hamilton Jenkin 1981, 99; Greeves 1986, 4-20; Newman 1996, 143-9;	35	
Henscott Consols	514	North Wheal Betsy, (?) Wheal Eliza	Mary Tavy	BI, Mary Tavy		
Hexworthy	69	Hooten Wheals, Henroost, Wheal Unity, Wheal Princetown, Holme Moor	FoD	Burnard 1891, 97; Collins 1912, 509; Dines 1956, 729; Harris 1968, 50-2;Hamilton Jenkin 1974, 99-101; Le Messurier 1967, 51; Atkinson et al 1978, 11; Burt et al 1984, 73; Greeves 1986, 4-20	35	P
Hillbridge Consols	194	Hillsbridge, Wheal Saturday, North Wheal Friendship(P)	Mary Tavy	Collins 1912, 505; Dines 1956, 710-11	107	
Holme Moor (Holne)	111	Hooten Wheals, Hexworthy(P), Wheal Unity, Henroost, Wheal Princetown, Ringleshutes	Holne	Collins 1912, 510; Burt et al 1984, 74; Greeves 1987, 4		
Holming Beam	128	Wheal Mist Tor, Omen Beam	FoD	Lysons 1822, 275;Le Messurier 1966, 87; Barton 1968, 110	36	P
Holne Chase	73	Chase	Holne	Dines 1956, 737; Hamilton Jenkin 1981, 108-9; Burt et al 1984, 74	37	P
Holne Park	59	South Plain Wood(P)	Holne	Hamilton Jenkin 1981, 105; Dines 1988, xxxvi	38	
Holwell	415		Widecombe	Dines 1956, 731		
Homerton	129	Wheal Forest, Overton	Okehampton Hamlets	Dines 1956, 751-2		
Hooten Wheals	112	Hexworthy(P), Henroost, Wheal Unity, Wheal Princetown, Holme Moor	FoD	Le Messurier 1966, 65; Harris 1968, 50-2	35	
Hope, Wheal	344		Mary Tavy	Lysons 1822, 273		
Huckworthy Bridge	249	Wheal George, East Wheal George, Wheal Huckworthy	Walkhampton	Rowe 1896, 269; Dines 1956, 698; Hamilton Jenkin 1974, 81; Burt et al 1984, 75;	69	
Huckworthy, Wheal	345	Huckworthy Bridge, Wheal George(P), Willsworthy	Walkhampton	Lysons 1822, 273	69	
Hughes, East	5	East Hewas	Walkhampton	Newman 1987, 8-10	39	P

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Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Huntingdon	54	Avon Consols, Devon Wheal Vor, Devon Consols Tin, New Huntingdon, Dartmoor Fores, East Wheal Rose	Dean Prior/ FoD	Burnard 1891, 111; Dines 1956, 729-30; Le Messurier 1967, 50; Atkinson et al 1978, 35; Brooke 1980, 75-6; Hamilton Jenkin 1981, 85-6; Burt et al 1984, 75; Greeves 2001, 8-10;	7	P
Huntingdon, New	117	Huntingdon, Devon Wheal Vor, Devon Consols Tin, Avon Consols, Dartmoor Forest, East Wheal Rose	Dean Prior/FoD	MacAlister 1912, 80; Dines 1956, 729	7	
Ilsington	442	Haytor Consols(P)	Ilsington	Dines 1988, xxxiv	9	
Industry, Wheal	134	Whiteworks(P)	FoD	Hamilton Jenkin 1981, 93-4; Greeves 1980, 11-16; Greeves 2002	40	
Ivybridge Consols	258	Fillham	Ivybridge	Collins 1912, 511; Dines 1956, 740-1; Hamilton Jenkin 1974, 137-8; Burt et al 1984, 75		
Ivytor (Ivy Tor)	233	Belstone Consols, Prince of Wales, Taw River	South Tawton	Rowe 1896, 269; Collins 1912, 511; Dines 1956, 753; Hamilton Jenkin 1981, 67; Burt et al 1984, 75; Dines 1988, xl;	84	P
Jewell, Wheal (Huel)	85	Jewel, Wheal Budlar, Wheal Freindship, Budlake, Budleybeer	Mary Tavy	Maton 1797, 297; Lyson 1822, 273; Collins 1912, 513; Dines 1956, 710; Pearse-Chope 1967, 271; Raistrick 1967, 23; Barton 1968, 156; Dickinson 1977; Hamilton Jenkin 1981, 36-8; Burt et al 1984, 76	85	P
Julian	107	Wheal Sidney, Julien	Plympton	Hamilton Jenkin 1974, 123; Burt et al 1984, 76		
Katherine, Wheal	9	Crane Lake, Eylesbarrow, Ailsborough	FoD	Cook et al 1974; Newman 1999, 105-148	41	P
Keaglesborough	41	Keagle Borough, Keaglesburrow	Walkhampton	Lysons 1822; Dickinson 1977;	42	
Kelly	295		Lusleigh	Collins 1912, 514; Atkinson et al 1978, 35; Burt et al 1984, 76-7		
King of the Dart	56		Buckfastleigh	Barton 1968, 107; Hamilton Jenkin 1981, 103; Dines 1988, xxxvi;	43	P
King's Oven	208	Water Hill, West Vitifer	Chagford	Broughton 1968/9, 15; Atkinson et al 1978, 39; Burt et al 1984, 77; Passmore 1997, Newman 2002, 44	44	P
King's Wood	55		Buckfastleigh	Dines 1956, 731, 740; Hamilton Jenkin 1981, 88		
Kingset	472		Walkhampton	Crossing 1912, 101	45	P
Kingsett & Bedford	518	Wheal Betsy, Wheal Freindship	Mary Tavy	BI, Mary Tavy		
Kit	180	Sheepstor	Sheepstor	Dines 1956, 704; Hamilton Jenkin 1974, 86-7; Atkinson et al 1978, 39; Burt et al 1984, 77-8; Richardson 1992, 89-93	99	P
Kitts	196	Wheal Reform, Lydford Consols	Lydford	Dines 1956, 711; Hamilton Jenkin 1981, 26	100	P
Kitty	311		FoD	Burt et al 1984, 78	101	P
Knight of the Dart	57	(?)Blackpool	Buckfastleigh	Barton 1968, 107; Hamilton Jenkin 1981, 104	46	P
Knock	255	Steeperton, Wheal Virgin	FoD	Le Messurier 1966, 65; Le Messurier 1967, 50; Greeves 1985, 101-27;	47	
Lemon, Wheal	39	East Ashburton	Ashburton	Hamilton Jenkin 1981, 124-5	48	P
Lopez, Wheal	34	Plymouth and Dartmoor Mining Co; Devon Wheal Lopez, Lopes	Bickleigh	Arx 1993, 90-2; Collins 1912, 523; Dines 1956, 685; Hamilton Jenkin 1974, 117-19	110	
Lucky, Wheal	91	Luckey	Walkhampton	Lysons 1822, 273; Burt et al 1984, 80	75	P
Lydford Consols	197	Wheal Reform, Kitts(P)	Lydford	Rowe 1896, 270; Dines 1956, 711; Hamilton Jenkin 1981, 26; Burt et al 1984, 80;	100	
Macclesfield	64	Brookewood, Emma, Buckfasleigh Manor, South Devon United	Buckfastleigh	Hamilton Jenkin 1981, 93; Newman 2005	16	
Maria	231	East Wheal Maria, Okehampton Wheal Maria	Okehampton Hamlets	Collins 1912, 528; Dines 1956, 754; Hamilton Jenkin 1981, 63; Burt et al 1984, 80		
Maria, East Wheal	312		Okehampton	Rowe 1896, 269; Collins 1912, 528; Burt et al 1984, 81;		
Marquis	361	Bedford United	Tavistock Hamlets	Lysons 1822, 275; Hamilton Jenkin 1974, 30; Brooke 2001,12		
Mary	434	Battishill, Kitts	Bridestow	Dines 1988, xxxi		
Mary Anne	435	Kitts	?Lydford	Dines 1988, xxxi		
Mary Emma, Wheal	19	Wheal Mary(?)	Lydford	Rowe 1896, 270; Collins 1912, 530; Dines, 1956, 711; Hamilton Jenkin 1981, 27; Burt et al 1984, 82	49	P
Mary Hutchings, Wheal	35	Hemerdon Consols	Sparkwell	Dines 1956, 688; Harris 1968, 55; Hamilton Jenkin 1974, 125; Burt et al 1984, 82-3'		
Mary, Wheal (2)	338		Walkhampton	Lysons 1822, 273		
Massey (Massah), Wheal	493		Horrabridge	BI, Horrabridge		

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Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Meavy Consols	525		Meavy	Bl, Meavy		
Meldon	130		Okehampton Hamlets	Dines 1956, 751-2; Hamilton Jenkin 1981, 58		P
Mercy, Wheal	368		Lydford	Lysons 1822, 275		
Merripit, Lower	315	Whreal Kitty(?)	FoD	Burt et al 1984, 83		
Merrivale Bridge	287	Wheal Fortune(P), Merrifield, Morefield Bridge	Whitchurch	Greeves, 1976, 3-5	29	
Mid Devon Mine	237	Belstone Consols (P), Taw River, Copper Hill, Sticklepath Hill	Belstone	Collins 1912, 534Dines 1956, 752; Burt et al 1984, 84		
Mist Tor, Wheal	97	Holming Beam(P), Omen Beam, Mistor	FoD	Greeves 2006, 12		
Monks Hill (Monkswell)	494		Sampford Spiney	Wood's map of Dartmoor 1850		
Noemia	316		Shaugh	Burt et al 1984, 87-8		
Nounder, Wheal	538			Greeves & Newman 1994, 216		
Nuns (Cross)	317		Walkhampton	Lysons 1822, 273; Barton 1968, 108; Burt et al 1984, 88	50	
Nuns, East	327		FoD	Woods 1850	51	P
Oke, Wheal	355		Okehampton	Lysons 1822, 275		
Okehampton Consols	452		Okehampton	Dines 1988, xxxix	92	P
Okehampton Wheal Maria	451	Devon Copper	Okehampton	Dines 1988, xxxix	68	
Okement Consols	453	Forest, Homerton	Okehampton	Dines 1988, xxxix		
Overton	98	Homerton, Wheal Forest	Okehampton Hamlets	Dines 1956, 751		
Owlacombe	53	Ashburton United, Union, Stormsdown, Owlacombe Beam & Union,	Ashburton	Lysons 1822, 275; MacAlister 1912, 81; Collins 1912, 542; Dines 1956, 735-6; Harris 1968, 56; Hamilton Jenkin 1981, 118-25; Burt et al 1984, 88-9; Dines 1988, xxxv	98	P
Peckpits	328		North Bovey	Lysons 1822, 273		
Peter Tavy & Mary Tavy Consols	296		Peter & Mary Tavy	Rowe 1896, 270; Collins 1912, 551; Burt et al 1984, 83, 90		
Peter, Wheal	357		Peter Tavy	Lysons 1822, 275		
Pewtor	530		Whitchurch	Greeves & Newman 1994, 216		
Phoenix, Wheal	460		Bickleigh	Rowe 1896, 269		
Piggiford	469		?	Brooke 2001, 11		
Pink,East Wheal	92		???	Dickinson 1975, 102-8		
Plumley	214		Bovey Tracey	Dines 1956, 726; Atkinson et al 1978, 42; Burt et al 1984, 90-1		
Plym Consols	7	Plymouth Consols	Walkhampton	Newman 1987, 8-10	52	P
Poldice	86	Walkham and Poldice	Buck Mon	Dines 1956, 694-5; Dickinson 1975, 102-8	73	
Poldice, Devon	165	Old Poldice, WakhamUnited (P)	Buck Mon	Rowe 1896, 269; Collins 1912, 468; Burt et al 1984, 44	73	
Poldice, East	341		Buck Mon	Lysons 1822, 273		
Poldice, Old	164	Walkham United (P), Devon Poldice	Buck Mon	Collins 1912, 612; Dines 1956, 695	73	
Prince of Wales	454	Ivy Tor (P), Taw River	South Tawton	Bl, South Tawton	84	
Prophecy, Wheal	93			Dickinson 1975, 102-8		
Prosper, Caroline Wheal	15	Caroline	Buckfastleigh	Dines 1956, 739-40; Hamilton Jenkin 1981, 87-8; Newman 2004	53	P
Prosper, Wheal	51		FoD	Geeves, 1975, 6-7; Atkinson et al 1978, 50	54	P
Providence, Wheal	455		FoD	Le Messurier 1979, 71	55	P
Queen of the Dart	42		Ashburton	Collins 1912, 563; Harris 1968, 61; Barton 1968, 107; Hamilton Jenkin 1981, 101; Burt et al 1984, 93; Brown 1995;	56	P
Ramsley (Hill)	227	Sout Zeal Consols, Wheal Emily, Fursdon	South Tawton	Collins 1912, 564; Dines 1956, 753; Le Messurier 1966, 65; Harris 1968, 62; Hamilton Jenkin 1981, 73; Burt et al 1984, 93; Greeves 1995, 59-64	28	P
Rattlebrook	47		FoD	Dines 1956, 711-12; Atkinson et al 1978, 47; Greeves 2003	4	P

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Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Reed	422		Christow	Dines 1956, 745		
Reform, Wheal	198	Kitts(P), Lydford Consols	Lydford	Dines 1956, 711; Hamilton Jenkin 1981, 26	100	
Riley	426		Hennock	Dines 1956, 748		
Ringleshutes	100	Holne (Holme) Moor	Holne	Dines 1956, 729; Le Messurier 1967, 50; Atkinson et al 1978, 49	57	P
Ringmoor Down	331	Ringmoor and Sheepstor	Sheepstor	Lysons 1822, 273; Greeves 1997a, 7	58	P
Rippon Tor	378		Ilsington	BI, Ilsington		
Rixhill, West	150	East Crebor, East Crowndale, South Crowndale,	Whitchurch	Hamilton Jenkin 1974, 66; Burt et al 1984, 83 94		
Robert, East Wheal	3	Wheal Robert, Sortridge Consols (P)	Sampford Spiney	Henwood 1843; Collins 1912, 567; Dines 1956, 695-7; Hamilton Jenkin 1974, 78	89	
Robert, North Wheal	126	Wheal Franco, Wheal Franco Consols	Horrabridge	Rowe 1896, 269; MacAlister 1912, 81; Dines 1956, 698; Hamilton Jenkin 1974, 77-8; Burt 1984, 95;	90	P
Robert, South Wheal	176	North Roborough Down(?), Wheal Franco	Horrabridge	Dines 1956, 702; Burt et al 1984, 95		
Robert, Wheal	125		Sampford Spiney	Collins, 1912, 567; Barton 1968, 173; Hamilton Jenkin 1974, 77		
Roborough Down	506	Roborough Down South, North	Buck Mon	BI, Buck Mon		
Roborough Down, North	174	South Wheal Robert(?)	Horrabridge	Dines 1956, 702; Burt et al 1984, 95	64	P
Roborough Down, South	175	Wheal Buller, Devon Wheal Buller	Buck Mon	Collins 1912, 428; Dines 1956, 702		
Rock Hill	318		Ilsington	Burt et al 1984, 95		
Rose, East Wheal	246	Huntingdon, Devon Wheal Vor, Devon Consols Tin, Avon Consols, New Huntingdon, Dartmoor Forest	Dean Prior	Brooke1980, 74-6; Greeves 2001, 8-10	7	
Rose, Wheal	243	Walkhampton Consols	Walkhampton	Dines 1956, 699	59	P
Roundhill	543	Wheal Harmony, Wilkins	FoD	Greeves 1997a, 7		
Rundlestone	546		Walkhampton	Greeves & Newman 1994, 204-5; Greeves 1997a, 7		
Runnaford Coombe\Combe	43	Coombe\Combe	Buckfastleigh	Bradford Barton 1969, 112; Hamilton Jenkin 1981, 90; Dines 1988, xxxvi	21	P
Ruth, Wheal	252	Ailsborough, Eylesbarrow(P), Dartmoor Consols, Dartmoor Consolidated	Sheepstor	Hamilton Jenkin 1974, 88-9; Cook et al 1974, 161-214; Newman 1999, 105-48	1	
Sampford Spiney Great Consols	531		Sampford Spiney	Greeves & Newman 1994, 216		
Sarah	450		Sourton	Dines 1988, xxxix		
Saturday, Wheal	334	North Wheal Frienship	Mary Tavy	Lysons 1822, 273; Hamilton Jenkin 1981 43		
Shaptor	215		Bovey Tracey	Dines 1956, 726; Atkinson et al 1978, 43; Burt et al 1984, 98-9		
Shaugh	102		Meavy	Collins 1912, 579; Dines 1956, 686; Barton 1968, 172; Hamilton Jenkin 1974, 119-20; Burt et al 1984, 99; Fletcher 2000		
Sheepstor	496	Kit(P); Sheepstor & Ringmoor (?)	Sheepstor	Richardson 1992, 89; Greeves 1997a, 7	99	
Sheepstor and Lyd River	507	Sheepstor, Kit	Sheepstor	BI, Sheepstor		
Shotts	319		Ilsington	Burt et al 1984, 100		
Shuttamoor	216		Christow	Dines 1956, 726; Atkinson et al 1978, 43; Burt et al 1984, 100		
Sidney, Wheal	104		Plympton	Lysons 1822, 273; Rowe 1896, 269; Collins 1912, 579; Dines 1956, 686; Harris 1968, 55; Hamilton Jenkin 1974, 125; Burt et al 1984, 100-1	97	P
Sigford Consols	40		Ilsington	Rowe 1896, 269; Dines 1956, 734-5; Hamilton Jenkin 1981, 125; Burt et al 1984, 101; Dines 1988, xxxv	60	P
Silverbrook	38		Ilsington	Collins 1912, 579; Dines 1956, 734; Hamilton Jenkin 1981, 127; Burt et al 1984, 101; Dines 1988, xxxv	61	P
Skirraton	485	Skerraton	Dean Prior	BI, Dean Prior		
Smallacombe	222		Ilsington	MacAlister 1912, 82; Collins 1912, 580; Dines 1956, 733; Hamilton Jenkin 1981, 137; Burt et al 1984, 101-2		
Smith, Wheal	363		(?) Tavistock	Lysons 1822, 275		
Smith's Wood Smith's Wood (cont)	1 1		Ilsington Ilsington	Rowe 1896, 269; Collins 1912, 581; Dines 1956, 734;Hamilton Jenkin 1981, 126; Burt et al 1984, 102; Dines 1988, xxxv	62	P

Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Smith's Wood (cont)	1		Ilsington	102; Dines 1988, xxxv	62	P
Somerset	155	Haytor Consols(P)	Ilsington	Bl, Ilsington	9	
Sortridge and Bedford	121	Westdown	Horrabridge	Dines 1956, 694;		
Sortridge Consols	2	West Wheal Robert	Horrabridge	Collins 1912, 581; Dines 1956, 695-7; Harris 1968, 60; Hamilton Jenkin 1981, 75-7; Burt et al 1984, 102-3	93	P
Sortridge Consols, East	120	Great Sortridge, Great Sortridge West	Whitchurch	Rowe 1896, 269Dines 1956, 693; Hamilton Jenkin 1974, 75-7		
Sortridge Consols, West	122	Little Gem (P), Walkham Valley	Buck Monachorum	Dines 1956, 695; Barton 1968, 107; Hamilton Jenkin 1974, 75-7; Burt et al 1984, 103; Rendell 1996, 10	74	
Sortridge, Great	119	East Sortridge, West	Whitchurch	Dines 1956, 693; Hamilton Jenkin 1974, 75-7	70	P
Sortridge, Great West	118	Great Sortridge Consols, East Sortridge	Whitchurch	Dines 1956, 693; Hamilton Jenkin 1974, 75-7		
Sourton Down Consols	430	Sourton Consols	Sourton	Dines 1956, 751; Barton 1968, 173		
South Plain Wood	60	Holne Park	Holne	Hamilton Jenkin 1981, 105; Dines 1988, xxxvi	38	P
South Zeal Consols	228	Ramsley, Wheal Emily, Fursdon	South Tawton	Williams 1861, 100; Dines 1956, 753; Hamilton Jenkin 1981, 73; Burt et al 1984, 119	28	
St Ann, Wheal	448	Bradford Pool	Drewsteignton	Dines 1988, xxxix		
Stancombe	320		Ilsington	Collins 1912, 583; Burt et al 1984, 104; Dines 1988, xxxv		
Steeperton	10	Wheal Virgin, Knock	FoD	Dines 1956, 751; Atkinson et al 1978, 47; Burt et al 1984, 104; Greeves 1985, 101-27	47	P
Sticklepath Hill Mine	226	Mid Devon, Copper Hill, Taw River, Belstone Consols (P)	Belstone	Hamilton Jenkin 1981, 68	83	
Stormsdown	321	Owlacombe(P), Ashburton United, West Beam, Wheal Union, Wheal Brothers	Ashburton	Dines 1956, 735; Harris 1968, 56; Hamilton Jenkin 1981, 122; Burt et al 1984, 104-5	98	
Surprise, Wheal	36	Whitchurch Down Consols	Whitchurch	Lysons 1822, 273, 275; Dines 1956, 691; Hamilton Jenkin 1974, 75; Harris 1990, 13; Dines 1988, xxviii; Greeves & Newman 1994, 216	82	P
Susan, Wheal	519		Mary Tavy	Bl, Mary Tavy		
Swinecombe Vale	260	Deby Hole, Gobbet, Wheal Cumpston	FoD	Hamilton Jenkin 1974, 98-9; Burt et al 1984, 106		
Tavistock Consols (Great)	236	Old Anderton, New Anderton, Rixhill, Wheal Ash	Whitchurch	Hamilton Jenkin 1981, 66	95	
Tavistock United	235	Old Anderton, New Anderton	Whitchurch	Dines 1956, 692; Hamilton Jenkin 1981, 66; Burt et al 1984, 113	95	
Tavistock, Wheal	362		Tavistock	Lysons 1822, 275	95	
Taw River	225	Mid Devon, Copper Hill, Sticklepath Hill Mine, Belstone Consols (P)	Belstone (P)	Dines 1956, 522; Hamilton Jenkin 1981, 68	83	
Teign	423		Doddiscomsleigh	Dines 1956, 747		
Teign Valley	322		Brideford	Burt et al 1984, 110-11		
Teign Valley Mining Company	512	Great Week	Chagford	Burt 1984, 110		
Teignmouth	441	Haytor Consols(p)	Ilsington	Dines 1988, xxxiv	9	
Throwleigh	432	Gooseford, Wheal Fortune	South Tawton	Bl, South tawton		
Tincroft, Devon Great	473	East Birch Tor, Birch Tor and Vitifer	Manaton	Barton 1968, 103; Newman 2002, 45		
Tool, Wheal	360		(?) Tavistock	Lysons 1822, 275		
Torwood	449	Fanny, Tor Wood	Bridestowe	Dines 1956, 751; Hamilton Jenkin 1981, 54; Dines 1988, xxxix	87	P
Treeby, Wheal	324		Buckfastleigh	Hamilton Jenkin 1981, 97; Newman 2005, 37	104	P
Treeby, Wheal	408		Plympton	Collins 1912, 590	16	
Union, East Wheal	373		Buckfastleigh	Barton 1968, 171		
Union, Wheal	343	Owlacombe(P), Ashburton United, Stormsdown, Ashburton Consols, Beam	Ashburton	Lysons 1822, 273	98	
Union, Wheal (Devon)	181		Peter Tavy	Dines 1956, 704; Rowe 1896, 270		
United Dart Mines	323		Buckfastleigh	Burt et al 1984, 112		
United Mines	459		Tavistock/Whitchurch	Rowe 1896, 270		

Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Unity, Wheal	333		Mary Tavy	Maton 1797, 297; Lysons 1822, 273; Pearse-Chope 1967, 271;Greeves 1997a, 7		
unknown, Cudlippton Down	549		Peter Tavy	-	113	P
Victoria, New (South Devon)	70	Druid, Arundell(P), Devon New Copper, Ashburton Tin & Copper,	Ashburton	MacAlister 1912, 80; Collins 1912, 538, 608; Dines 1956, 636-7; Hamilton Jenkin 1981, 113-7; Burt et al 1984, 113; Nance & Nance 1996, 109-22; Von Arx 1995; Newman 2003 , 173-218; Hamilton Jenkin 1981, 111-16	5	
Virgin, Wheal	495	Steeperton(P), Knock	FoD	Greeves 1997a, 7; Greeves 1985, 101-27	47	
Virgin, Wheal	371	Beardown (P), Bear Down	FoD	Greeves 2002a, 28	11	
Virginia	521		Ashburton	BI, Ashburton		
Virtuous Lady	169		Buck Mon	Lysons 1822, 275; Rowe 1896, 269; Collins 1912, 608; Dines 1956, 700; Harris 1968, 60; Barton 1968, 173; Hamilton Jenkin 1974, 47-8; Burt et al 1984, 113-4; Brooke 2001, 13	81	P
Vitifer	32	Viteford, Birch Tor & Vitifer, Vytifor, Dartmoor Tin Mines	North Bovey	Lysons 1822, 273; Collins 1912, 66, 416; Dines 1956, 720-4; Le Messurier 1966, 65; Le Messurier 1967, 50; Raistrick 1967, 21-2; Broughton 1968/9, 7; Hamilton Jenkin 1974, 101-7; Newman 2002, 28-36	12	
Vitifer Consols, New	209	West Vitifer	Chagford	Passmore 1997, 28-33; Burt et al 1984, 114	65	P
Vitifer, East	26	Agnes	North Bovey	Broughton 1968/9; 56, Dines 1956, 724; Atkinson et al 1978, 17; Burt et al 1984, 114	63	P
Vitifer, New	477	West Vitifer	Chagford	Barton 1968, 189; Passmore 1997, 28-33;	65	
Vitifer, West	206	New Vitifer Consols	Chagford	Dines 1956, 723-4; Broughton 1968/9, 15;Broughton 1971; Hamilton Jenkin 1974, 107; Atkinson et al 1978, 44; Passmore 1997, 28-33;	65	
Vor, Devon Wheal	115	Huntingdon(P), Avon Consols, Devon Consols Tin, New Huntingdon, Dartmoor Forest, East Wheal Rose	Dean Prior	Hamilton Jenkin 1981, 85	7	
Walkham and Poldice	166	Devon Poldice, Walkham United(P)	Buck Mon	Dines 1956, 694; Burt et al 1984, 115	73	
Walkham United	163	Devon Poldice, Walkham and Poldice	Buck Mon	Collins 1912, 612; Dines 1956, 695; Burt et al 1984, 115	73	P
Walkham Valley	245	West Sortridge Consols, Little Gem(P), Walkham United	Whitchurch	Dines 1956, 695	74	
Walkham, Wheal	540			Greeves & Newman 1994, 216		
Walkhampton Consols	168	Wheal Rose(P)	Walkhampton	Dines 1956, 699; Barton 1968, 172	59	
Water Hill	413	Kings Oven(P)	North Bovey	Dines 1956, 723	44	
Water, Wheal	138	Hemsworthy, Somerset, Haytor Consols(P), Bagtor	Ilsington	BI, Ilsington	9	
Waye Alston	522		Ashburton	BI, Ashburton		
Week Consols, Great	27	Greatweek, Teign Valley Mining Company	Chagford	Dines 1956, 750; Broughton 1971; Atkinson et al 1978, 48; Hamilton Jenkin 1981, 82; Burt et al 1984, 68,	88	P
Wellington Consols, Duke of	439	Wheal Frederick(P), Foxhole	FoD	Barton 1968, 109; Dines 1988, xxxi; Greeves 2003, 23;	31	
Westdown	497	Sortridge and Bedford	Whitchurch	Dines 1956, 694		
Whiddon	62	Whiddon Down, Wheal Widdon, Widdon Smelting House Tin and Copper	Ashburton	Donn 1765; Dines 1956, 736; Hamilton Jenkin 1981, 117; Homer 1996, 155-69; Burt et al 1984, 115; Lysons 1812, 273;Dines 1988, xxxv; Brooke 2001, 46-7; Amery 1925, 43-52	66	P
Whiddon and Brownshill	133	Widdon Smelting House Tin and Copper, Whiddon(P)	Ashburton	Dines 1956, 736; Hamilton Jenkin 1981, 117	66	
Whitchurch Down Consols	326	Wheal Surprise(P)	Whitchurch	Hamilton Jenkin 1981, 75		
White Works (1786)	94	Wheal Industry, New Whiteworks	FoD	Greeves 1986, 2; Greeves 2002, 3-6	40	
Whitemoor Mead	330		Walkhamptom	Lysons 1822, 273; Greeves 1997a, 7		
Whiteworks (Great)	482	Wheal Albert (P), Wheal Florence	Plympton	Warden-Page 1892, 151; Collins 1912, 612; Dines 1956, 730; Le Messurier 1967, 50; Greeves 1980, 11-16; Greeves 1986, 2; Greeves 2002, 3-6; Hamilton Jenkin 1981, 93-4; Atkinson et al 1978, 45; Burt et al 1984, 116; Lysons 1822, 273; Harris 1968, 46; Greeves 1997, 7(DTRG)	2	
Whiteworks, New	505	Great White Works (P), Wheal Industry	FoD	Greeves 1996; Greeves 2002	40	
Whitleigh, Wheal	143	Wheal Gennys, Whiteley	Plympton	Collins 1912, 612; Dines 1956, 686; Hamilton Jenkin 1974, 130-1; Burt et al 1984, 116		
Widdon Smelting House Tin and Copper	132	Whiddon(P), Whiddon and Brownshill	Ashburton	Dines 1956, 736; Hamilton Jenkin 1981, 117; Barton 1968, 173	66	
Wilkins	544	Wheal Harmony, Roundhill	FoD	Greeves 1997a, 7		

Appendix (cont)

Name of Mine	A	Alternative and Associated Names	Parish	Bibliographical References	B	P
Willsworthy	488	Huckworthy Bridge, Wheal George (P)	Sampford Spiney	Hamilton Jenkin 1974, 78-80		
Willsworthy	195		Mary Tavy	Dines 1956, 711; Barton 1968, 168	112	P
Wray	211			Dines 1956, 725; Atkinson et al 1978, 46		
Wrey Consols	37	East Brookwood(p)	Holne	Hamilton Jenkin 1981, 91; Burt et al 1984, 117	17	
Yarner	99	Wheal (Frances) Francis, Yarrow	Bovey Tracey	Rowe 1896, 269; Collins 1912, 613; Dines 1956, 732; Harris 1968, 62; Hamilton Jenkin 1981, 139; Burt et al 1984, 118	30	P
Yarrow	135	Yarner(P), Wheal Frances (Francis)	Bovey Tracey	Hamilton Jenkin 1981, 139	30	
Yennadon	433	Wheal Yennadon, Meavy Iron	Meavy	Hamilton Jenkin, 1974 85-6; Greeves & Newman 1994, 216	103	P
Yennadon, Wheal	526	Meavy Iron, Yennadon	Buck Mon	Bl, Meavy	103	
Yeoland Consols	158	South Yeoland, East Yeoland, Plymouth Yeoland	Buck Mon	Collins 1912, 613; Dines 1956, 702-3; Harris 1968, 55; Hamilton Jenkin 1974, 114-7; Burt et al 1984, 118; Dines 1988, xxix	67	P
Yeoland, East	96	Yeoland Consols	Buck Mon	Dines 1956, 702-3; Hamilton Jenkin 1974, 114-7	67	
Yeoland, Plymouth	159	Yeoland Consols, South Yeoland	Buck Mon	Hamilton Jenkin 1974, 114-7	67	
Yeoland, South Wheal	157	South Huel Yeoland, Yeoland Consols, Plymouth Yeoland	Buck Mon	Collins 1912, 613; Dines 1956, 702-3; Hamilton Jenkin 1974, 114-7; Burt et al 1984, 119	67	
Zeal Manor	509		South Tawton	Bl, South Tawton		

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Abbreviations

AMP – abandoned mine plan (Devon Record Office)

BI (with parish) Brook Index (Westcountry Studies Library)

CCRO – Chester & Cheshire Record Office

CRO – Cornwall Record Office (Truro)

DA – Dartmoor Archive

DCNQ – *Devon and Cornwall Notes and Queries*

DNP(A) – Dartmoor National Park (Authority)

DRO – Devon Record Office (Exeter)

DTRG – Dartmoor Tinworking Research Group

EFP – *Trewman's Exeter Flying Post*

IoM – Report by the Inspector of Mines (Parliamentary Papers)

MJ – *Mining Journal*

OS – Ordnance Survey

SYM – *Sherborn & Yeovil Mercury*

TG – *Tavistock Gazette*

WDRO – *West Devon Record Office* (Plymouth)

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