Technology, Ideology and Environment

The Social Dynamics of Iron Metallurgy in Great Zimbabwe, AD 900 to the Present

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Abstract

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This thesis provides insights into the nature and organization of iron technology associated with past and present communities of Great Zimbabwe in southern Africa. Written accounts, ethnographic enquiries and, results of archaeological field surveys and excavations are combined to provide the first detailed account of Great Zimbabwe's iron production technologies. The existence of a considerable iron industry in Great Zimbabwe with complex and innovative designs and processes of iron smelting is established. Evidence includes tap slags, natural draft furnaces, one with a unique rectangular morphology, and the exploitation of manganese-rich iron ores or fluxes. Moderate to low levels of iron oxide in slag samples point to large-scale production of good quality iron for an extensive market at some time in the past of Great Zimbabwe. Iron slags, possible bloom pieces and broken tuyeres are examined using standard archaeometallurgical laboratory techniques to establish the decisions and choices underlying technology and pyro-metallurgical processes in and between sites. The results are explained using theoretical concepts of social practice and agency to address the worldviews, social values and beliefs of iron related practices in Great Zimbabwe over time.

The study provides an alternative angle for approaching the social complexity of Great Zimbabwe (with its peak in the 12th–16th centuries AD), previously understood from the perspective of its spectacular architecture. Evidence of primary and secondary production activities in domestic and specialized settings outside settlements suggests a greater spatiotemporal complexity and ambiguity of the organization of technology than previously thought. Iron production in domestic contexts provided an inclusive space, creating the possibility for transformation of not just materials, but also women and children into social agents of technology, adding an alternative and more socially embedded perspective of technology in Africa.

Keywords: Great Zimbabwe, Iron Metallurgy, Urbanism, Innovation, Landscape, Social Dynamics, Natural Draft, Forced Draft, Southern Africa, Archaeometallurgy, Anthracology, Archaeometry

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*To my loving and supportive wife Stella
Priscilla, my sweet-spirited sons Ezekiel
Anesuishe and Jesimiel Asher,
And to
My inspiring parents Wilson Qedisani and
Ednah Zinyanga, including my eleven sib-
lings, whom I all missed throughout this
study – may your joy be full.*

List of Papers

This thesis is based on the following papers, which are referred to in the text by Roman numerals.

- I. Mtetwa, E. In review. Iron metallurgy in the Great Zimbabwe hinterland: new archaeometallurgical field evidence, *AZANIA: Archaeological Research in Africa*.
- II. Mtetwa, E. In review. The bloomery iron technologies of Great Zimbabwe from AD 1000 – an archaeometallurgy of social practices. *Journal of Archaeological Science*.
- III. Mtetwa, E and Lindahl, A. manuscript. The Archaeometry of Tuyeres from Great Zimbabwe and Wider Implications for its Iron Production Technologies. To be submitted to the *Archaeometry* journal
- IV. Mtetwa, E. In press. Great Zimbabwe's iron: its technological materials and social space. In: Pikirayi, I (ed.) *The World of Great Zimbabwe*. New York: Routledge (peer reviewed)
- V. Mtetwa, E., Maposa, Y. C., Manyanga, M., & Chirikure, S. (2017). When the smith is a woman: innovation, improvisation and ambiguity in the organisation of African iron metallurgy. In: Manyanga, M. and Chirikure, S. (eds.), *Archives, Objects, Places and Landscapes: Multidisciplinary approaches to Decolonised Zimbabwean pasts*, 295-318. Bamenda: Langaa RPCIG.

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1 Introduction

1.1 Aims of the dissertation

I explore two mutually inclusive themes in this PhD thesis. The first is the nature of iron technology in Great Zimbabwe, one of the earliest and largest societies in southern Africa that experienced significant technological and sociopolitical transformations from c. AD 900. The second concerns the possibility of illuminating the changing worldviews, social values and cultural attitudes shaping and reshaped by iron related practices in Great Zimbabwe from c. AD 900 to the present. To that end, I examine material traces of indigenous iron metallurgy recovered from the wider archaeological landscape surrounding the urban centre to establish the key parameters of the technology, including the social organization of current smithing activities. My intention is to reveal technological variability in the iron metallurgy of Great Zimbabwe over time, which I explain as materializing broad scale changes in the social values and ideologies of the people of Great Zimbabwe over time. As such, I use the theoretical concepts of social agency and materiality to articulate the interrelated engagements within and between humans and their biophysical world. The following specific objectives further crystallize my research questions:

- To examine variability in the iron production technologies of the Great Zimbabwe area
- To determine the spatial and social organization of iron related practices in the wider archaeological landscape of Great Zimbabwe over time.
- To illuminate the dynamics of human-environment interactions in iron-related practices, particularly the social engagement with wood resources for metallurgical processes.

In sub-Saharan Africa at least, the production, consumption and circulation of iron are socially textured phenomena (see detailed review in Chirikure, 2015). By focusing on the iron industry of Great Zimbabwe, therefore, I unravel critical aspects of the everyday life of one of the earliest and largest societies associated with urbanism, social complexity and statehood in southern Africa.

For more than a century, researchers recurrently focused on the impressive architecture and space within the urban centre, essentially blurring the possibility of viewing settlement from the angle of its iron related practices. My study, therefore, can be seen as an answer to the numerous calls by varied scholars of Great Zimbabwe such as Garlake (1978), Sinclair (1987), Ndoro (2001), Fontein (2006) and Chirikure and Pikirayi (2008) to look beyond the impressive walls in conducting the archaeology of the drystone-built-capital. In their different research agendas, these scholars have challenged upcoming researchers like me, to take a renewed and more vigorous interest in the diverse material culture of Great Zimbabwe in developing an enriched and coherent history of the settlement.

In light of the above calls, enviable research efforts have already been invested in a variety of artefacts found within the constituent walled enclosures of the Great Zimbabwe urban centre (e.g. Bandama et al., 2017; Chirikure and Pikirayi, 2008; Herbert 1996; Matenga, 2011; Miller, 2002). One conspicuous omission, however, is the lack of focused research on the dynamics of social interactions established between the Great Zimbabwe urban centre and communities in the hinterland over time, especially in iron related practices. We lack a clear understanding of how the inhabitants of the Great Zimbabwe area socially engaged with each other across space and the surrounding biophysical landscape in the specialized production and consumption of iron – and other materials. The social and physical use of the immediate and broader landscape of Great Zimbabwe was undoubtedly an integral component in the people's everyday idea of the world and social life. In this study, therefore, I bring forward the significance of iron in the large-scale social, economic, political and environmental systems and processes of Great Zimbabwe. I also illuminate the hinterland of the prehistoric urban centre as a crucial section of the places making up the social networks that sustained the urban centre over a long period in mutual interactions.

1.2. Theoretical framework

Iron technology, in this study, is reconstructed and theorized as a dynamic process of mutual transformation between people and their material world in the everyday social practices of Great Zimbabwe, a notion inspired by Marcia-Anne Dobres (2000). Most important in this respect is the continuation of some indigenous iron related practices into our modern-day contexts in the form of casting and forging of scrap metals. These provide daily scenarios for conceptualizing crafts production practices within the broader context of changing social, economic, political and environmental systems and processes of modern-day rural and urban life in Zimbabwe. Great Zimbabwe is associated with the origins of social complexity, urbanism and statehood in southern Africa, reaching its zenith in the mid second millennium AD (Chirikure et al.,

2016; Huffman, 2014; Pikirayi, 2001). It bears marks of a sophisticated worldview characterized by the construction of drystone monumental architecture and consumption of a wide range of exotica from active participation in global trade. Such prosperity is understood to have developed on the backdrop of a solid agro-pastoral economy, land availability, religion, and a unique skill in crafts production and architectural engineering (Pikirayi 2017; Moffett & Chirikure 2016; Sinclair et al. 2012; Chipunza 1994; Garlake 1973; Pwiti 1991). The monumental architecture and disparate arts, interpreted elsewhere as conspicuous consumption (see Trigger, 2003), indicate the appropriation of high levels of skills and ideology and materials to produce and transform the social space of Great Zimbabwe (see also Matenga, 2011; Pikirayi, 2013).

The production of iron, therefore, is viewed as an integral component of the technological and sociopolitical transformations of Great Zimbabwe, which began towards the end of the first millennium AD in southern Africa (Mitchell, 2002; Phillipson, 2005). I view the material remains recovered within and around Great Zimbabwe's urban centre, including the current smithing activities, as materializing changes in the people's worldviews, social values and belief systems. This line of thought also builds on Conkey's (1993) thesis, that humans are materialists and symbolists simultaneously. Perhaps one of the most vivid examples depicting such a dual persona in the people of Great Zimbabwe is their use of blocks of banded ironstone to decorate one of the walls near the famous Conical Tower in the Great Enclosure of Great Zimbabwe. This illustration is just one example showing the ceremonial consumption of iron, even in its ore state. Another example is the ceremonial and utilitarian iron objects recovered from the urban centre, which have received considerable research attention (e.g. Chirikure, 2015, 2007, Herbert, 1996). As such, the remains of iron production debris explored in this study could provide a window of opportunity to address the shortfall in our knowledge of the cultural attitudes towards iron in Great Zimbabwe. Until now, iron, as a category of material culture has received very little archaeological attention in comparison to the reasonably well researched stone architecture, soapstone birds and figurines (Huffman, 1996; Matenga, 2011; 1993).

Because of my focus on the social dynamics of technology, the theories of social practice and agency as inspired by Pierre Bourdieu (1977) and Anthony Giddens (1984) are of central interest. An emphasis in these theories on the influence of the habitus, here referring to the worldview, social beliefs and values in shaping an agent's actions and thoughts is critical for illuminating how iron related practices are socially textured. I am equally interested in Henri Lefebvre's (1991) notions of social space and materiality as pursued and developed by a number of researchers in the last decades (see detailed review in Witmore, 2014) to unravel the archaeologies of Great Zimbabwe's iron. Thus, an understanding of iron technology as both a material and social space in which varied social agents co-existed has the potential to illuminate how unequal social power relations were negotiated in iron related practices.

Within socio-political and economic systems such as that of Great Zimbabwe, the appropriation of natural resources and manipulation of embodied technological knowledge in human agents tend to be highly contested social space, a phenomenon commonly encountered in the past and present societies of the world (Lefebvre 1991). The conventional view in the archaeology of African iron metallurgy has emphasized that such materials as reproductive organs depicted on furnaces and tuyeres, for example, are indicative of the politics of exclusion of women as agents of ritualized technology (e.g. Herbert, 1993; Killick, 1990). Through the conceptual tools highlighted, I intend to provide an alternative account of Great Zimbabwe's iron industry based on data sets some of which were unrecorded in previous researches.

Another important aspect theorized in this study is the spatial location of iron production, given that this had wider implications for the social organization of iron technology in terms of the configuration and reconfiguration of gender identities encompassed in technology (see Dobres et al., 1995). I do believe that the location of iron production within the domestic arena provided a context in which women and possibly children would have been socialized or negotiated their way into the world of iron, emerging as technological agents. Likewise, by entering into the domestic sphere, I will argue, iron production would have fitted into a broader fertility worldview materialized in organs of the female anatomy depicted on houses, pots, drums and headrests (Collett 1993; Chirikure 2005). This way of viewing these decoration crossovers has the potential to provide an alternative reading of iron technology in which female agency is far more prominent than currently projected. Some of the domestic contexts within the urban centre and wider archaeological landscape of Great Zimbabwe have yielded evidence of small-scale iron production, characterized by a rich application of external surface treatments and decorations of the bloomery furnaces (e.g. Bent, 1893; Sinclair, 1984). I contrast these materials with large-scale iron production sites concentrated in the hinterland, which lack traceable surface treatments but have significant internal ritual embodiments of the furnaces (e.g. Mtetwa, 2011).

So far, iron related practices in Great Zimbabwe have been understood and interpreted on the basis of the material traces recovered within the urban centre (Miller 2002; Herbert 1996; Bandama et al. 2016a). There remains a blurred picture of the social interactions established between the hinterland and the urban centre itself. The recurrent focus on metallurgical assemblages within the urban centre continues to give a false impression of technology as elitist, given that the main site of Great Zimbabwe was an important political, religious and trade centre. This is a phenomenon common in urban studies (see Wynne-Jones 2007:377). Wynne Jones' (2007) studied ceramics in the urban-rural areas of the Swahili regions and observed that people were producing and using articles of daily life, and that consumption patterns were similar across the urban/rural divide (Wynne-Jones 2007:377). The unequal distribution of such resources as iron ore and woodlands across the Great Zimbabwe

landscape underscore the fact that both the elite and non-elite inhabitants of Great Zimbabwe's seamless material space exploited the same resources. As explained by Lefebvre (1991), such a material space is an arena of interaction and convergence by various groups in which the rhythms of everyday life would have shaped and reshaped the production and appropriation of the social and material world.

Al Idrisi, writing around AD 1154, reports a thriving trade along the coast in iron obtained from the interior of southern Africa which he described as excelling that from India in quantity, quality and malleability (Prendergast, 1974). His remarks have the potential to show how the physical quality of southern Africa's iron, as a materiality, made social interactions with the other distant parts of the world to emerge. Conkey (1993) aptly described humans, our species, as materialists and symbolists simultaneously, which emphasizes the inseparability of the social and material world. A common theme among the varied approaches of materiality is that material things and social practices bring each other into being and are analytically indivisible (Jones 2004; Joyce & Joyce 2015; Witmore 2014). Witmore (2014), however, insists that material things should be prioritized for study in archaeology, not as backdrops of human lifeways, but for the reason that they are participants/actors with their own emergence and existence. This emphasis on materiality as an active agent helps me to approach the various groups of materials that actively participated in the iron production process and systems of Great Zimbabwe.

I conceptualize the archaeological and ethnographic contexts explored in this study suggestive of women's active participation in technology arena as historical realities that are often not factored when negotiating modern-day social spaces laden with unequal dimensions of gender representation. I intend to use some of my archaeological results and the ethnographic case of Mrs. Khohliwe Zanzi, a female smith discussed in Paper V, to mount an exhibition at the Mining, Engineering, and Transport Expo showing the role of women and traditional iron technology in the social reproduction of Zimbabwe's modern-day society. Thus, for me, the study of preindustrial iron technology is another way of approaching and contributing to the transformation of the social constitution of technology in my own modern-day world.

1.3. Synopsis of the papers

There are five papers making up this PhD thesis with each one of them exploring a specific theme under the overarching study of the dynamics of iron provisioning systems and processes in Great Zimbabwe from as early as AD 900 to the present.

Paper I (Mtetwa, E. in review) presents for the first time, detailed examples of iron metallurgy in the wider archaeological landscape of Great Zimbabwe

recovered from previous and current research. The paper gives the empirical background and grounding of this PhD thesis. Prior to this study, areas surrounding the urban centre were said to have a dearth of iron production debris. However as reviewed in this paper, previous excavations and surveys and also those presented in the course of this thesis project is now challenging this understanding. The paper reviews the evidence of different practices of iron technology in and around Great Zimbabwe. The growing number of recorded iron production sites and the different technological practices they embody provides a new understanding of the physical and social use of the Great Zimbabwe landscape. The paper reports the presence of a thriving industry in the wider archaeological landscape in the form of clusters of large circular furnace bases, heaps of tuyeres fused in multiple tap and flow slags, magnetite iron ores, including a rectangular furnace base.

Paper II (Mtetwa, E. in review) deals with the chemical and microstructural characteristics of the varied types of slags using ICP-AES and ICP-MS analyses techniques and a possible bloom sample analyzed metallographically. These data are used to identify and reconstruct the nature of technological decisions ironworkers undertook regarding raw materials, pyrometallurgical processes and key technological parameters in Zimbabwe. The results demonstrate the presence of sophisticated iron production technologies in the form of slag tapping, natural draft and varied fluxing techniques, which possibly included the addition of bones and other plant materials within ritualized contexts.

Paper III (Mtetwa, E and Lindahl, A. manuscript) discusses the XRF results of metallurgical tuyeres from different sites across the Great Zimbabwe landscape some of which were fused in multiples indicative of natural draft iron technology. Results show striking similarities and differences in clay resources selected for use between neighboring sites, suggesting the tendency to share resources as a cultural value, but also the adaptation of technology to local resources and cultural choices. The dominance of grains in the silt and sand fractions, which are a natural components of the clay selected, points to the time and skill invested in prospecting for clays that are self-tempered. On the other hand, the presence of crushed grains in the coarse sand and fine gravel in a few samples reflect the ability to deliberately correct the plasticity of clay whenever the naturally tempered clay sources were scarce in a particular area or over time. The paper also highlights how the selection and preparation of clays for ceramic technology would have had a direct contribution in the slag-metal separation, particularly in smelting iron ores with few gangue materials of their own.

Paper IV (Mtetwa, E. in press) makes use of the new archaeological field evidence to illuminate variation and change in the social organization of iron

technology in Great Zimbabwe. The iron production sites located within domestic contexts are drawn upon to argue for household-based production. This household-based production, it is argued would have included the whole household, including women. The paper also discusses that household production may have been a means to socialize children into the social world and technological skills related to iron production. Household-based production is also drawn upon to argue for transmission of technological skills along family lines, as observed in similar encounters in Sub-Saharan Africa. The use of large natural draft furnaces, which represents a significant change in techniques of iron production, is also considered to be indicative of change in the worldview of iron and iron related practices. The presence of literature indicating the uniqueness of natural draft to sub-Saharan Africa helps to dismiss biases in 19th century written records, which associated novel designs and processes of iron technology to European ancestry.

Paper V (Mtetwa et al., 2017) uses an ethnographic case study to problematize the conventional projection of iron technology as a male domain, a position that is common in global archaeology. By highlighting the contemporary reality of a female chief smith near Great Zimbabwe, the paper brings out the complexity and ambiguity of the social organization of technology and makes parallels with iron technology in the past based on written sources. The paper calls for theories and methods that treats women as agents of technology in prehistoric, modern and future contexts.

2 Background

2.1 Physical and socio-cultural background

In this chapter, I introduce the biophysical world of Great Zimbabwe, which was integral to the everyday life of its inhabitants and their neighbors in southern Africa. I consider, particular, aspects of the environment that are crucial to iron production and other cultural practices surrounding it. Although my focus lies on the geography of present day Zimbabwe in general and Great Zimbabwe in particular, the territory that fell under the influence of the latter was far bigger in the past. As pointed out by Ekblom et al (in press), the social networks of places under Great Zimbabwe would have included the region demarcated by the Mozambican coastal lowlands on the east. The Kalahari Desert bordered it to the west while the Soutpansberg range of mountains and the southern fringes of central Africa made its southern and northern limits respectively (see Chirikure et al., 2017).

2.1.1 The geology and mineral resources

Zimbabwe is one of several sub-Saharan African countries richly endowed with a diversity of mineral wealth (Figure 1). Geologically, about two thirds of the country, just like the large areas of South Africa and Botswana, is underlain by the granite-greenstone complex that forms the Zimbabwe Craton (Moore et al., 2009). The Craton is a part of the ancient continent of Western Gondwana with rocks dating back to the early Archaean Eon, about 3.46 billion years ago (Wilson et al., 1995). It is intruded by Zimbabwe's Great Dyke, a major linear layered mafic/ultramafic igneous complex, about 550 km in length, that cuts across the Zimbabwe Craton in a north-north-eastern direction (Armstrong and Wilson, 2000). The Great Dyke (see Fig 1), which is 2.5 billion years old, like many other mafic intrusions, is associated with economically important metals such as gold, chrome, nickel, copper, platinum, titanium, vanadium and tin. Importantly, it is also rich in iron ore deposits (Liu et al., 2014; Liu and Jin, 2014).

The diversified geology and richness of mineral resources of the Zimbabwe Craton have spawned a dynamic social engagement between humans and their material world since prehistoric times. During the Stone Age, the larger quartz and dolerite veins and dykes in the granite plutons of the Matopos, were quarried for the raw materials of varied lithic technologies (Walker, 1995). The

mineral resources, on the other hand, especially iron, gold, copper, tin, and lead have been mined and processed for subsistence and exchange within and beyond the continent since the first millennium AD (Cline, 1937; Hall, 1905; Summers, 1969; Swan, 2008, 2007, 1994).

Figure 1. Map showing some of the minerals of Zimbabwe and the location of Great Zimbabwe (modified from <http://www.lib.utexas.edu/maps/africa>)

Great Zimbabwe itself is situated on the southern edge of the Zimbabwe plateau within this Archaean complex of greenstones, mafic, ultramafic rocks, gneisses and migmatites, and late intrusive granites. Masvingo area as a whole is characterised by two forms of granite reliefs, gneissic granite which forms whalebacked hills and bornhardts, and the massive granite which gives rise to scattered castle kopjes, tors and dwalas (Lister, 1987). These formations have provided architectural foundations and granite blocks for monumental, stone-built structures associated with the Zimbabwe period (Pikirayi, 2001b).

Forming the skyline of the Great Zimbabwe landscape are the sharp ridges of the Nyanda, Nyuni and Beza Ranges that rise between 300 and 450 metres which are rich in banded ironstones and quartzites (Gwavava and Ranganai, 2009; Lister, 1987; Wilson, 1973). These iron-rich ores sustained premodern industrial iron metallurgy in the area from as early as the advent of metal-working and agro-pastoral communities in first millennium AD up to colonial times (Mtetwa 2011; Ndoro 1994). For instance, the Mount Buchwa area barely 100km west of Great Zimbabwe, has evidence of Matola/Silver Leaves pottery dated to the 3rd and 5th centuries AD, suggesting that its rich iron ore deposits attracted early metal working populations to this area (Huffman, 1978).

Matola/Silver Leaves pottery is associated with the spread of early farming communities into the interior of southern Africa during the first half of the first millennium AD (Mitchell and Whitelaw, 2005). In addition, Carl Mauch, a German explorer and geologist, who visited Great Zimbabwe in 1871, observed some smiths quarrying a chalk-slate containing ferruginous mica quarried from sources near the villages settlements, which they roasted, crushed, and reduced repeatedly over a period of one week (Burke and Mauch, 1969). He also observed that the ironworkers used the natural granite surfaces and stones to crush and reduce the ores into smaller fragments, demonstrating yet another social use of the Great Zimbabwe physiography landscape in processing and producing daily materials and artifacts.

The Zimbabwe Iron and Steel Company (ZISCO) and the Steelmakers Group Company, also known as SIMBI, are exploiting the rich iron deposits at Mount Buchwa and Nyuni Hills respectively. This indicates that the minerals in the broader regional landscape of Great Zimbabwe are integral to the social life of past and present communities in southern Zimbabwe, connecting them to global trade throughout time. Similarly, areas near the Bondolfi Mission, about 15km northwest of the Great Zimbabwe centre, have rich gold deposits. These deposits supported precolonial gold mining from the end of the first millennium AD (Phimister 1976; 1974), and are being exploited today too. The extraction of minerals, even in modern-day contexts of most communities in Sub-Saharan Africa, is embedded in cosmological and religious power structures, often replete with community and individual appeasement of ancestral spirits. These are viewed as owners of all mineral wealth and other

natural resources and as such are believed to be rewarders of all mineral extraction, offering protecting against mining hazards and natural disasters (Chirikure, 2015).

2.1.2 Topography and Drainage

Being located on the southern margins of the Zimbabwe plateau, the Great Zimbabwe and surrounding area straddles the highveld on the northern end and the middle veld to the south, the latter one an elevation between 600-1200 m above sea level (Kay, 1970). The Zimbabwe plateau (Fig 3), is a broad, southwest-northeast oriented topographic plateau, which forms the central watershed of the country. It separates the Zambezi River basin to the north and the Limpopo and Save River basins to the south and southeast. The highveld is characterized by an old surface of a low undulating relief and long, flat horizons, which, however, progressively increases in height to nearly 2600 m at the summit of Inyangani (Lister, 1987; Moore et al., 2009). The mountain ranges together with the Zimbabwe plateau make up the country's highveld, a region of areas over 1200m above sea level (Kay, 1970).

Figure 2. The location of Great Zimbabwe on the margins of the highveld, and the agro-ecological zones of Zimbabwe (Modified from Hentze et al. 2016)

The drainage systems are of high relevance for the understanding of iron-practices and use of environment more broadly. There is a marked difference in the character of the river systems to the north and south of the Zimbabwe central watershed. Immediately north of the central watershed, the country is characterised by a mature drainage network, with meandering rivers and low gradients in broad shallow valleys (Lister, 1987), providing more surface water to local communities. In contrast, the rivers to the south of the central watershed, oriented southeasterly, are younger in age and characterised by steeper gradients as well as more deeply incised, rectilinear courses. A typical example is the Mutirikwi River, the largest and longest in the Great Zimbabwe catchment, which carries very small amounts of water because of rapid run-off generated by a steep gradient from the hilly terrain. As such, groundwater is the major source of consumable water in the Great Zimbabwe area, a scenario obtaining in many rural areas of Zimbabwe (Maclear et al., 2002). A recent study of the Great Zimbabwe area's current water consumption and conservation patterns discovered an abundance of natural springs, with some of them active throughout the year (Pikirayi et al., 2016). These natural springs, would have provided the much-needed water for metallurgical activities apart from domestic consumption and watering of livestock.

Figure 3. The drainage system of Zimbabwe and major rivers crossing the Great Zimbabwe landscape (modified from Moore et al 2009)

Compared to the adjacent Limpopo and Save lowvelds, which receive less than 600mm of rainfall per annum (Manyanga, 2006), the Great Zimbabwe urban centre and immediate vicinities enjoy a favorable microclimate – possibly a function of past human activity. Much of the rain comes in the form of mist, locally known as *guti*, which, together with its numerous natural springs, as mentioned above, make the Great Zimbabwe area a water-rich landscape that supports the production of grain and other crops (Bannerman 1982; Pikirayi 2001; Pikirayi et al. 2016). The hilly topography around the urban centre, in particular, precipitates moisture from prevailing southeasterly winds, resulting in a mean annual precipitation of between 800-1000 mm, which is relatively sufficient for crop production. Thus, such a local climate, an easily tilled soil, ample timber and firewood as well as small game would have attracted varying population groups to settle in the Great Zimbabwe over millennia (Garlake, 1973).

2.1.3 Settlement history

The geological features in the area have been an integral part to the lifeworld of the Great Zimbabwe inhabitants over time, both when it comes to ironmaking practices, as will be discussed here, but also older practices of ritual and representation of a society's worldview. Rock art sites such as Chamavara and Chesvingo near Great Zimbabwe indicate an intimate interplay between the worldview of hunter-gatherers and the physical formations of Great Zimbabwe's granite landscape. As generally observed across the Zimbabwe plateau and adjacent lowlands, Late Stone Age hunter-gatherer communities (c. 13 000 to 1 500 years ago) seem to have been pursuing a semi-sedentary lifestyle, as evidenced by storage pits in rocky hills and grindstones in their settlements (Jonsson, 1998; Walker, 1995). Though of limited extent, rock art is found on panels and shelters around Great Zimbabwe, similar to the more extensive rock-art sites found in other parts of Zimbabwe and southern Africa as a whole (Garlake, 1982; Lewis-Williams et al., 2000; Walker, 1995). The cultivable land and fertile loamy soils in the narrow valleys between the numerous granite hills attracted the settlement and development of populations with an agro-pastoral lifestyle, attested in the Great Zimbabwe area from around the mid-first millennium AD (Bandama et al., 2016; Collett et al., 1992; Summers et al., 1961).

Towards the end of the first millennium AD, there was a gradual emergence of larger population and power centers in southern Africa (Sinclair 1987; Chirikure et al., 2013; Huffman, 2009; Kim and Kusimba, 2008). These were characterised by a novel drystone architecture that utilized the natural bedrock formations, a phenomenon lavishly demonstrated at Great Zimbabwe and such other urbanized centres as Khami, Naletale and Dlodlo in central Zimbabwe. As pointed out by Ndoro (2001), the granite boulders, rock outcrops and shelters, which were incorporated into some of the stone enclosures of the

urban centre, would have been crucial in materializing human perceptions of the world and social power (see also Pikirayi, 2013). In Shona worldview, such boulders are the abode of venerated ancestral spirits, which made Pikirayi (2013) argue that the construction of monumental architecture in the Zimbabwe Culture involved the manipulation of ideology and nature to create social power (see also Knox, 1985).

2.1.4 Vegetation

Secure access to wood resources is crucial for iron production and innovation. Unfortunately, there is still little data on long-term vegetation change in the region. Wild and Fernandes compiled the most detailed mapping of vegetation in Zimbabwe in the mid-20th century. The vegetation of the country today is predominantly *Brachystegia-Julbernadia* (miombo) woodlands, with large areas of *Colophospermum mopane* (mopane) woodlands in the Zambezi basin in the north and the Limpopo basin in the south (Brenan et al., 1968; Hedberg and Hedberg, 1968; Müller, 1994). Areas in the west and south-west of the country are covered extensively by woodlands dominated by *Acacia* and *Combretum* species (Müller, 1994). The Save and Limpopo Basins to the southeast and south of Zimbabwe are dominated by mopane woodland (*Colophospermum mopane*), well known for their timber and charcoal production (Wild and Fernandes 1968; Venter et al. 2003). The southern section of the Great Zimbabwe landscape, in particular around Mushandike, has an abundance of mopane woodlands. Archaeological charcoals from the urban centre and iron production sites have confirmed its popular use for domestic and metallurgical purposes (Chikumbirike, 2014), as will be discussed in more detail below.

Owing to a long-history of human settlement and considerable population size, traditionally estimated at 20 000 inhabitants (Huffman, 1996), it has been suggested that there have been significant changes in the condition and state of the vegetation of Great Zimbabwe (Figure 2). The assumption is that this open landscape was due to degradation by inhabitants of the Great Zimbabwe for domestic fuel, timber, and clearing of agricultural fields (see also Bannerman 1982). For Bannerman (1982), the population of Great Zimbabwe would have grown beyond the carrying capacity of the surrounding landscape, citing the absence of *Brachystegia spiciformis* within the urban centre as an example of environmental degradation. Studies of photographic records from Great Zimbabwe also show that vegetation was more open in the late 19th - early 20th century than today (see review in Chikumbirike 2014).

Figure 4. Vegetation map of Zimbabwe showing the location of Great Zimbabwe (Modified from Hentze et al. 2016)

However, these assumptions have not adequately factored in the vegetation management policies adopted by various regimes curating the Great Zimbabwe monument right from the onset of colonial administration of the site around 1900 AD. The construction of a golf course around the monument at the height of colonial rule in Zimbabwe, for instance, also saw many more trees being cleared from the monument. Also, as a way of controlling vegetation from affecting the drystone walls at the site, but also as a way of improving the visibility of the walls for visitors, site managers have periodically cleared away trees and creepers from the monument ever since (Ndoro, 2001).

Studies conducted in southern Africa on savannas and savanna woodlands show that these tend to be ecologically unstable, given the region's vulnerability to high incidences of rainfall variability within and between the rain seasons (Ekblom, 2012; Ekblom et al., 2012; Holmgren et al., 2012). Though research is still limited, some studies have made use of pollen records to reconstruct human-environmental interactions and the results so far suggest that there is little evidence indicative of change in the forest taxa around population centers. One example is the study from Thulamela, one of the Zimbabwe tradition sites in South Africa dated between AD 1400 and 1650 (Ekblom et al., 2014). Chikumbirike's analysis of archaeological charcoals recovered from within the Great Zimbabwe urban centre and Chigaramboni ironworking site also confirmed that there is no significant difference between the vegetation species reflected in the archaeological record and the contemporary landscape (Chikumbirike, 2014a). This suggests that woodland management strategies designed to enhance sustainable exploitation of varied forest taxa may have been more diversified and efficient than previously imagined. The numerous myths, taboos and legends associated with current vegetation resource management strategies of such sacred groves as Norumedzo in Bikita near Great Zimbabwe provides an ethnographic reality crucial for understanding situations in the deep past (e.g. Mawere, 2013, 2012). There is need for a more detailed research focusing on the environmental history of such local areas as Great Zimbabwe to augment the picture derived from regional studies highlighted above, as another way of unlocking its past (see Pikirayi in press).

2.2 Previous research on iron technology in Great Zimbabwe

2.2.1 The Great Zimbabwe urban centre

Paper I presents more detail on the research background. I summarize this discussion here for the benefit of the general reader. The earliest European visitors to southern Africa observed iron production technologies that were still in operation in the 19th and 20th centuries. In Great Zimbabwe, the earliest European observers, Carl Mauch and Theodore Bent for example, reported

widely about the low shaft forced draft iron smelting technology, whose furnaces and tuyeres were invariably sexualized (Bent, 1893; Burke and Mauch, 1969). Together with the local contemporaries, these earliest ethnographers' reports excluded or poorly represented earlier types of iron technologies of Great Zimbabwe that were visible in the archaeological record of their localities. For instance, Carl Mauch took notice of the presence of multiple fused tuyeres around Great Zimbabwe, but local contemporaries allegedly dismissed the iron production debris as stemming from an earlier generation of 'white people' credited with building the Great Zimbabwe (Burke & Mauch 1969: 136–137). Mauch and his local contemporaries highlighted the radically different technological styles in the same locality over time, but associated a visibly complex iron technology to a superior white race.

The encounter between archaeologists and the evidence of iron production started as early as the 1890s (Bent, 1892; Caton-Thompson, 1931; Hall, 1905; 1909; Willoughby, 1893). Together with other mundane materials at Great Zimbabwe such as pottery, these were viewed as essentially disconnected from the history of the site. David Randal MacIver was the first to assess all categories of material culture found within the stone ruins, including metal artifacts, from which he proposed the African authorship and medieval date of Great Zimbabwe for the first time (Randall-MacIver, 1906). Further excavations by Gertrude Caton-Thompson (1931) recovered a larger corpus of finished iron weapons and tools which she also interpreted as of African shape and manufacture. While she acknowledged that the metal objects were soundly crafted, she thought, however, that metal alloys had been imported from outside (Caton-Thompson, 1931: 64). It was not believed that production had taken place locally. The recurrent focus on the Great Zimbabwe site as a foreign product during the early decades of research at the site obscured the significance of its iron production debris, which reflected the entire sequence of the iron production process. Chirikure & Pikirayi (2008) note that up until the 1980s, research at Great Zimbabwe remained biased by colonial understandings, which obscured an understanding of the local history of metal production. In addition, the long period of vandalism that marked the early years of research at the site further fragmented the archaeological record of iron production within the site (Bandama et al., 2016a; Garlake, 1973; D Miller, 2002)

In the 1990s, Herbert (1996) took special interest in the growing corpus of iron production debris from previous surveys and excavations within the Great Zimbabwe centre. These artifacts represented the entire sequence of iron metallurgy at the site in the form of iron ores, furnace rubbles, slags, metalworking equipment, finished tools and other metal objects (Herbert, 1996: 643–644). At the heart of Herbert's studies was an attempt to understand the link between metals and power, mundanity and sacredness from the perspective of the given co-existence of daily utilitarian (e.g. hoes, axes, chisels) alongside more prestigious items such as spears and ceremonial axes. Her hypothesis proposing

that primary metal extraction took place within royal spaces of the site formed an interesting line of research in later studies on the production, consumption and distribution of metals in Great Zimbabwe. In particular, Chirikure and colleagues set out to explore the spatial distribution of iron production debris from different sections of the urban centre, recovering more evidence of smelting and smithing activities such as tuyeres with run-back slag and an assortment of other types of slag (Bandama et al., 2016a; Chirikure, 2015, 2007b; Fredriksen and Chirikure, 2015). These studies have shown that every section of Great Zimbabwe's dry-stone-built capital bore remnants of metal extraction, secondary smithing and finished products, which they think suggest household-based production by royal family members themselves (Chirikure 2007: 88; Bandama et al., 2016: 12).

2.2.2 Looking beyond the urban centre

While the studies highlighted above reflect the complexity of the social organization of iron technology within the urban centre, they overlooked the growing number of recorded iron production sites in the hinterland, and how these related with the centre itself over time. In 1991, Webber Ndoro conducted archaeological surveys in an area 10 km west of the Great Zimbabwe site aiming to establish prehistoric settlement patterns and obtain a greater understanding of the wider cultural landscape around the prehistoric urban centre (Ndoro 1994). He identified 21 sites comprising one rock art paintings site, an Early Iron Age settlement, nine terminal Zimbabwe Culture sites and ten iron smelting sites. These are located in the Chigaramboni mountain ranges, which lie on a north/south axis and form a plateau that continues to the Great Zimbabwe site. *Brachystegia* and *Apocynaceae* tree species dominate the entire plateau while granite hills scattered on the same plateau are mainly of haematite iron-stones, which would have supported the development of metallurgical activities in the area. Three of the recorded iron smelting sites consisted of a few furnace bases, very small amounts of slags and funnel shaped single tuyeres, which typically suggests the use of bellows driven furnaces (Chirikure et al. 2009). The other seven sites had large heaps of tuyeres and very thick pieces of collapsed *dhaka* furnace walls. As reported by Ndoro, many of the tuyeres were fused in multiples, some having more than ten pieces measuring 8 cm mean diameter on both ends indicative of natural draft iron smelting technologies (Prendergast 1975; Killick 1991).

Even earlier, Paul Sinclair conducted rescue excavations at Gokomere Mission, about 40km north of Great Zimbabwe, recovering a furnace decorated with breasts and dated to the turn of the 19th century AD (Sinclair 1984). The latter furnace contrasts sharply with those excavated by Ndoro in the Chigaramboni hills, which had diameters as wide as 1.4 m in average and were concentrated in as many as five furnaces in one locality. The important point

here is that Sinclair and Ndoro's excavations revealed interesting technological variability and innovation in Great Zimbabwe, as observed in the history of African iron metallurgy (e.g. Cline, 1937; Killick, 1990; Mapunda, 1995). These new findings raise questions regarding the technological history of Great Zimbabwe in particular and southern Africa as a whole, which could not be asked from materials recovered from the urban centre.

Apart from Sinclair and Ndoro's works mentioned above, a few other studies are worth mentioning with regards iron metallurgy in the hinterland of the Great Zimbabwe urban centre and the country at large. Lorraine Swan conducted surveys in the Malilangwe Trust Estate, more than a 100km south-east of Great Zimbabwe (Swan, 2007; 2008a). She excavated both Early Farming and Zimbabwe Period iron working activities where two sites, Hlambamlonga and Mhangula, were seen as possible iron sources for the Great Zimbabwe state. The large-scale nature of these sites, the absence of any large settlement nearby and contemporaneity with Great Zimbabwe suggested that they supplied Great Zimbabwe with some of its iron (Swan, 2007). Of equal significance are the excavations conducted in other parts of Zimbabwe where materials similar to those recovered around Great Zimbabwe have been discovered. Prendergast (Prendergast, 1979; 1975), for instance, discovered for the first time, the presence of natural draft furnaces in northern Zimbabwe dated to the 14th and 15th centuries AD. Again, Chirikure recorded extensive iron production sites in northern and eastern Zimbabwe reflecting greater variability, including the possible use of natural draft and slag tapping techniques at Swart Village site (AD 800 -1200). Within variation, these findings in northern Zimbabwe provide a general framework for conceptualizing the technology and chronology of archaeometallurgical materials discovered by Ndoro in the Chigaramboni hills, a point that I will return to later on.

2.3 New investigations in the hinterland of Great Zimbabwe

In 2010, I received a report about an extensive large-scale iron working site near Gaths Mine in Mashava 40km north-west of Great Zimbabwe, which I investigated as part of my MA dissertation work with the University of Dar es Salaam in Tanzania. With the help of archaeology students from the Midlands State University in Zimbabwe, I conducted intensive foot surveys within a kilometre radius of the iron-smelting site. We identified at least twenty possible furnace bases, each one measuring at least one metre in internal diameter and these were in association with large amounts of multiple fused tuyeres, blocky furnace rubble, and dense slags. Other slag pieces were cylindrical in shape and some were flat, bearing flow marks indicative of the use of slag

tapping techniques at the site (Mtetwa, 2011). I discussed results of the technological analyses of selected slag samples from this site, whose low levels of iron oxide indicate an efficient iron smelting approach. The materials underpinned an intensive use of natural draught iron smelting technology akin to the materials discovered by Ndoro and Prendergast mentioned above. These few known examples of iron smelting technologies from Chigaramboni hills and Mashava sites inspired me to undertake a broader study of the iron metallurgy in the wider archaeological landscape of Great Zimbabwe for my PhD project with Uppsala University in Sweden. I deal with the various social and technical questions of the study in the five papers making up this thesis. In the next chapter, I address the data collection and analyses methods I adopted to explore the iron industry of Great Zimbabwe area.

3 Methodology and material

The Great Zimbabwe cultural landscape carries, arguably, one of the most extensive and diverse records of iron production technologies in southern Africa, as demonstrated in Paper I. The significance of these materials is that they are tangible traces for reaching and understanding of varied aspects of the everyday social practices of the Great Zimbabwe people over time. Importantly, unravelling the inseparable relationship between the material world and social meaning in past and present societies requires an inter-disciplinary approach, which straddles qualitative and quantitative research methods common in humanities and natural sciences respectively (Kothari, 2004). In this study, I combine a number of approaches in ethnography, community archaeology, archaeometallurgy, archaeometry and archaeobotany. My personal experiences of growing up in socio-cultural and environmental settings similar to those in modern-day contexts of the local communities around Great Zimbabwe constituted yet another source of value to this study.

3.1 Ethnography and written record

In studies of past iron production technologies of sub-Saharan Africa, ethnography has been a profitable approach in understanding and interpreting the social contexts within which iron related practices emerged and changed over time (Chirikure, 2005; Cline, 1937; David et al., 1989; Herbert, 1993; Humphris, 2010; Killick, 1990; Mathoho et al., 2016; Peter R Schmidt and Mapunda, 1997). Archaeologists have used some or all of the different approaches found within ethnography such as oral traditions, direct historical testimonies, detailed observations, interviews as well as primary and secondary documents to explore the societies' worldviews, beliefs and cultural values.

One of the session abstracts for the Eighth World Archaeological Congress (WAC-8) 2016 in Kyoto, Japan, under the theme of Science and Archaeology carried the title, "Social Archaeometallurgy: The Role of Metals within and between Societies." The session organizers, Prof Mark Pollard and colleagues, remarked that the dominance of ethnography and anthropology in Africa and Latin America has tended to make archaeometallurgy more social than technical (Pollard et al., 2016: 298-290). Interestingly, their call to discuss multiple issues embedded in social archaeometallurgy by researchers from different

archaeometallurgical traditions echoes an earlier appeal made at another conference in 1996. In the Archaeology and Anthropology of Mining Conference held at the Rockefeller Foundation's Bellagio Study and Conference Centre on Lake Como in Italy (22-26 July 1996), the organizers made a call to studying extinct and extant mining and metallurgical communities as a social phenomenon (Knapp et al., 1998). Clearly, these repeated calls over the years underscore the potential of ethnographic approaches in unravelling such issues as the social context of production, gender, power strategies and labour exploitation, imperialism and colonialism (Knapp, 1998). None of these themes, could be dealt with in the traditional studies of ancient technologies, which focused explicitly on the technical aspects of production, as pointed out by Dobres (2000). This underscores the appropriateness of ethnography for the current study.

When used with appropriate sampling for interviewees and skillful probing during oral interviews, ethnographic studies have the potential to bring out a multi-vocal perspective and deep-seated attitudes, beliefs and values embedded in the social practices of a society. A typical example is the study of iron working in southern and western Uganda by Dr. Louise Iles where a chance interview with a female respondent revealed that women were deeply involved in iron production, a dimension that male respondents never highlighted in earlier interviews (Iles, 2016). In the end, Iles, echoing the call by Schmidt (1998) and Arthur (2010) invited researchers to look beyond one gender as an agent of technology in order to reach and discuss its social constitution. This way of research has the potential to yield alternative and more socially nuanced insights into past and present crafts production in Africa. Recurrently, focus has been laid on the male gender during interviews on precolonial technologies of Africa (see Killick, 1990; Mapunda, 1995). Unfortunately, this has entrenched the stereotype of women as technologically naïve.

3.1.1 Direct observations and interviews

Inspired by the above reviewed debates and studies, for this study, I chose to carry out detailed observations and interviews of a female smith living near the prehistoric urban centre of Great Zimbabwe, who has been conducting independently organized forging and casting of scrap metals with her family members since the 1950s. Together with my research assistant, Yananiso Maposa, we recorded video clips of Mrs Kohliwe Zanzi, popularly known as Mbuya (grandma) Murozvi, forging a ceremonial hand axe (*humbwa*) besides a smithing hearth (*chido*) with the help of one of her grandsons. We also captured more video clips and photographs of the female smith and one of her sons forging a hoe (*badza*), and her daughter-in-law carving a wooden handle (*mupinyi*) for the hoe. It is important to highlight that prior to interviewing the elderly artisan, we sought permission from the Chief himself, who sanctions such researches in his communal area. We also conducted interviews with

male and female members of Chief Charumbira communal area aiming to establish their attitudes towards Mbuya Murozvi and her family, who also is a renowned potter and producer of snuffing tobacco among several other crafts. Paper I is dedicated to the complexities and ambiguities of gender within a field of technology traditionally associated with males and a rural context conventionally viewed as rigidly hierarchical, where men top the ladder of power and creativity. In my future researches on gender and technology, I intend to include women in other technologies together with their male competitors to explore how the masculine and feminine aspects of our being human contribute to power, knowledge and technology.

Eyewitness accounts of iron production activities recorded by European visitors to Sub-Saharan Africa before and during the colonial period remain a critical source of valuable information to archaeologists (e.g. Chirikure, 2006; Killick, 1990; Mapunda, 1995). Unfortunately, there is a dearth of written records for much of the earlier technological history of Great Zimbabwe up to the 19th century AD. Only a few written accounts exist covering the second half of the 19th century AD (Bent, 1892; Burke and Mauch, 1969). Although few, these records illuminate important aspects of the operational chain of iron production in the form quarrying of the iron ore, roasting, crushing, reduction, labor, furnace types, decorations as well as ritual performances during the smelt. I provide more information about their observations under the results sections in Chapter 4 and in Paper I.

3.2 Archaeology

As illustrated in the foregoing sections, ethnographic sources and written records are important in adding layers of understanding to the archaeological data. However, the archaeological source material itself has been key in constructing a better understanding of the technological skills and innovation in Zimbabwe and beyond. The archaeological data used in this thesis include both studies of pre-existing collections, surveys and archaeometallurgical analyses. In addition, wood charcoal analysis has been commissioned on material from archaeological sites. I explain the different archaeological approaches used and methods employed in detail below.

3.2.1 Legacy Collections

The Great Zimbabwe Conservation and Research Centre holds a fair amount of archaeometallurgical materials on its storerooms, recovered from spontaneous surveys and excavations within and around the urban centre by previous researchers (e.g. Ndoro, 1994). In the planning phase, I examined these assemblages to establish their value as sources of archaeological explanation.

This also involved searching for the field reports generated during the respective surveys and excavations. Unfortunately, I could not find any excavation notes. Although this makes working with legacy data a bit difficult, Bandama et al. (2017) profitably reconstructed aspects of Great Zimbabwe's metallurgical crucibles using such data. In my case, I found the details captured in the accessions register, excavation photographs and site index cards quite useful in building up background information to the collection in question, but also in planning the fieldwork. Discussions with researchers as Dr. Webber Ndoro and Prof Paul Sinclair who previously worked in and around Great Zimbabwe (see chapter 2.2) were important, in particular Sinclair's participation in two of my field reconnaissance surveys.

3.2.2 Community Archaeology: a brief note

In African Archaeology, there is an ever-growing call to produce knowledge in collaboration with local communities as a way of decolonizing archaeological and heritage management practice (Chirikure et al., 2008; Pikirayi and Schmidt, 2016; Pikirayi, 2016). Within this approach, archaeologists are viewed as co-producers rather than leaders of archaeological projects through sharing resources, decision-making and knowledge with members of local communities. Inspired by this approach, I introduced my study to various local leaders including Chief Fortune Charumbira and to his council of village heads at the communal court. Because of this rapport, local leaders took it upon themselves to introduce the project to their respective villagers, encouraging people to report archaeometallurgical remains they frequently encounter in their maize fields. Apart from opening up for ethnographic surveys already discussed in section 3.1.1., the collaboration also assisted in identification of new archaeometallurgical sites. This introduction led to a series of more discussions at some of the known iron production sites, where samples of the research materials were exhibited and explained. I also gathered invaluable information regarding transportation of iron ores and wood.

3.2.3 Archaeological field surveys

Archaeological field surveys are not just a step towards excavations. They are also a means to answering archaeological questions regarding the physical and social use of the landscape (e.g. Pwiti, 1996; see also McIntosh, 2005; Wright, 2010 for urban landscapes). So far, archaeologists are still unclear about the source of Great Zimbabwe's iron, doubting if there are iron production sites in the hinterland supplying the centre with metals (e.g. Bandama et al., 2016; Chirikure, 2015; Chirikure et al., 2017). Thus, I set out from the beginning of the PhD study to survey and record iron production sites in order to illuminate the presence and analyze shifting distributions and concentrations of iron working activities over time in areas.

The field surveys were conducted from October 2013 before the onset of the rainy season when visibility of archaeological materials on the ground is at its best. However, the surveys skirted the Mutirikwi Recreational Park immediately to the north as the Parks and Wildlife Management Authority did not grant a research permit. The Great Zimbabwe's mosaic landscape was divided into four broadly defined landforms: river valleys, cultivable land, whale-backed hills and stand-alone granite features such as bornhardts, castle kopjes and tors. These units were subjected to intensive foot surveys by a team of seven participants (including three archaeology students from the Great Zimbabwe University who were on attachment at the Great Zimbabwe World Heritage Site, two local committee members, one curator of archaeology and a surveyor from the National Museums and Monuments of Zimbabwe). Scatters of slags, tuyere fragments, broken furnace rubble and iron-ore quarry sites were documented using a GPS and camera. The range of materials was recorded to tease out the various technologies practiced at the site and their social settings (Chirikure, 2005; Killick, 1990). Samples of beads, pottery, and a clay figurine were collected for further analysis and curation at the GZCRC (see summary table of sites and finds in Table 1).

3.2.4 Archaeological excavations

Owing to constraints of time and funds, I prioritized sites exhibiting poorly understood technologies such as large concentrations of multiple-fused tuyeres, slags and possible furnace for excavations as shown in the next section. Thus, I conducted excavations at three different sites in the wider cultural landscape of Great Zimbabwe namely, Boroma, Veza 1 and Mutevedzi. In addition, I have also included material from Mashava, which I excavated in 2010; Goose Bay, excavated by David Collett in 1986; and Chigaramboni, excavated by Webber Ndoro in 1991. Below are the descriptions of the archaeological excavations, including some brief notes about the sites under investigation (see Table 1).

3.2.4.1 Boroma Site

Boroma site lies approximately four kilometres northeast of Great Zimbabwe World Heritage Site, making it one of the iron working sites closest to the urban centre. Intra-site surveys at Boroma site identified two distinct activity areas – an iron smelting and smithing locations, the latter in association house foundations. Broken furnace rubble, slags and tuyeres occurred at the foot of granite boulders nearest to Chebopopo stream and numerous natural springs. The natural springs in this area, which were recorded during a survey of Great Zimbabwe's water resources (see Pikirayi et al., 2016), are key to agricultural and domestic usage of water, and would have been exploited for iron production activities in the past. Remains of iron smithing activities, in the form of a possible smithing hearth, slags, and flat surfaced granite blocks, were located

less than 200m further west of the smelting activity area on a low-lying granite rock outcrop where run-off continues to erode away artifacts. Isolated domestic artifacts such as a piece of green and white chinaware, a potsherd with cross hatched lines and an iron hoe blade were collected from the cultivated land between the smelting and smithing areas. These were too few to shed adequate light towards our understanding of the period of occupation and the contemporaneity of the settlement and the iron working activities.

Three 2 x 2 m trenches were excavated at Boroma site in order to locate furnace remains. Trench 1 was located in an area of dense scatter of tuyeres and furnace rubble in supposedly less disturbed eastern edges of cultivated land. The trench was excavated to a depth of 20 cm when a hut floor was found, no archaeological materials from this trench and it was therefore abandoned.

Trench 2 was located right at the foot of one of huge boulders that bordered the eastern edges of the cultivated piece of land where there was the densest scatter of broken tuyere, furnace rubble and blocks of slag. The trench was excavated in spits to a depth of about 60 cm depth (Figure 3). The soil was sieved using a 4x4 mm sieve. The first spit (0-10 cm), which was largely made up of humus, contained a mixture of tuyeres, slags and furnace rubble. Dark-brown soil and a dense mixture of furnace rubble, multiple fused and single tuyeres, and a few fragments of furnace slags characterized the second spit (10-20 cm). The eastern end of the trench yielded a charcoal bed from which samples were collected for both radiocarbon dating and tree species identification. The third spit (20-40cm), a continuation of the dark brown soils from the second spit, yielded more tuyeres, and slags with plant impressions. Below this layer was a reddish brown layer which yielded some roots and stones after which was a sterile layer.

The third trench enclosed a possible smithing hearth on top of a low-lying granite whaleback, locally known as *ruware*, which borders the western edge of the piece of cultivated land between the two iron working areas. Because of the shallow soil, Trench 3 was excavated to a depth barely 10 cm before reaching the surface of the rock outcrop. The structure measures about 100cm in diameter, with an average wall thickness of 10cm and a depth of 15cm. The ground immediately outside the structure seemed plastered and pole impressed mud, *dhaka*, was scattered around, which suggests that the hearth had a possible shelter around it. The trench yielded undiagnostic potsherds and few pieces of slag. At least three house foundations were identified on the same rock outcrop next to the smithing hearth, illustrating the complexity and ambiguity of technological organization in African iron metallurgy.

The excavations at Boroma Site recovered iron slag, broken tuyere pieces, furnace rubble, and charcoals. The bulk of slag from Trench was made up of large cake like blocks, the largest one measured about 15 x 13 cm, and a thickness of about 7 cm, suggesting that these were furnace slag. Some of these blocks had plant impressions and possible bone inclusions. Trench 3 yielded

small slag pieces of amorphous shape measuring 3 x 2 cm on average. The slag had very low magnetism and was very porous. At least 30 broken tuyere pieces measuring at most 15 cm in length were recovered from Trench 2. A maximum of four broken tuyere pieces were found fused together, suggesting that the smelting process used natural draft air supply mechanism. Both single and multiple-fused tuyere exhibited evidence of vitrification and collapse at the distal end, indicating that these were inserted deep into the furnace where they were affected by very high temperatures. The internal diameter of the different tuyeres recovered at Boroma site ranged between 30 and 40 cm, while their external diameter measured between 50 and 60cm.

Figure 5. Boroma Site, Trench 2 West Facing Wall.

3.2.4.2 Veza A site

The Veza 1 iron working site is located about 8 km south-west of Great Zimbabwe. It is situated at the foot of the western slope of a large granite inselberg and is bounded on the south by the Veza River about 100 metres away, which would have supplied water for the iron production activities at the site. Right within the site is an abandoned modern homestead whose flowerbeds and courtyard were demarcated using blocks of finger-impressed and vitrified furnace rubble. Members of the abandoned homestead also heaped blocks of iron slag (measuring approximately 20 x 15 cm) together with granite stones on the family graves located on the western side of the site. Other blocks of slags, furnace rubble and pieces of tuyere were cleared from the land surrounding the homestead in preparation for maize cultivation and made into large heaps on the edges of the fields. Foot surveys around the site identified more iron production debris towards the top of the granite inselberg about 800 m east of the main site. The site has a striking density of very small sizes of iron slag that spreads out over an area of about 3 hectares.

A 2 x 2 m trench was located at the centre of the homestead where a concentration of broken tuyeres, slag pieces and blocks of furnace rubble was noticed protruding from the ground and being partially exposed by soil erosion. The homestead area was expected to produce high quality material for dating and archaeometallurgical analyses as compared to the rest of the site, which was disturbed from years of ploughing. The trench was excavated by a combination of arbitrary spits and natural stratigraphy to a depth of 40 cm. The first layer, an arbitrary spit of 10 cm, exposed more broken tuyere pieces clustered together with amorphous slag pieces and vitrified blocks of furnace rubble than were visible on the surface. Its soil, composed by gritty earth or gravel, was compacted. The second layer, about 10 – 30 cm thick, yielded much more of the same archaeometallurgical materials than those excavated in the first spit. In addition, there were charcoal fragments within the the cluster of tuyeres and slag pieces. These iron production debris rested on the vitrified floor a possible furnace pit, which dipped slightly westwards (Figure 6; see also Paper 1, Figure 7). The final layer, about 10 cm, was entirely gritty earth and sterile.

Figure 6. The floor plan of Level 3 and north facing wall of the excavation trench at Veza A site.

3.2.4.3 Mutevedzi site

Mutevedzi site is located 6km south-west of Great Zimbabwe World Heritage Site. The site is located on a pass where two hills, one on the east and the other on the west, flanked the iron working location. A perennial stream, Shambinyara, flows past the site some 200m away to the north, which would have supplied water for the iron working activities at the site. A dense scatter of slag, tuyere fragments and furnace rubble spread across an area covering 3 hectares. A thriving business centre was established within the boundaries of

this site, destroying some of the archaeometallurgical heritage during the construction of retail stores of Mutevedzi Business Centre, also known as Nezvigaro.

A large trench measuring 5 m x 3 m was situated between two shop buildings surrounding a cluster of at least twenty tuyeres tuyeres partially exposed by years soil of erosion (Figure 7, top right of photo). The trench was excavated by a combination of arbitrary spits and natural stratigraphy to a depth of about 50cm. The first excavation spit was an arbitrary spit about 10 cm thick, which was made up of layers of very dark reddish brown, dark reddish brown and dull reddish brown soils (see profile in Figure 7). Thick tree roots had grown into and in between some of the tuyeres clustered in this layer, breaking them apart over the years. The second layer had reddish brown, a continuation from layer one. It yielded more tuyeres, some of which fused in multiples in association with a rectangular furnace base. The furnace wall, which was about 15 cm thick, had visible finger impressions, vitrification, and evidence of a possible leakage of slag through the wall. The floor of the furnace sloped gently northwards and the southern end of the furnace was destroyed. The furnace base, which measured about 2 x 1 showed evidence of slag leakage through the cracks in its 10 cm thick wall. The rectangular furnace base is a unique design discovered at Mutevedzi site. It is unclear whether this furnace was once similar to the one described under Veza A above. Underneath this layer, the soil turned dark red and there were no more traces of cultural materials.

Figure 7. Mutevedzi trench stratigraphy (top). Rectangular shaped furnace base (bottom). Here note the cluster of tuyeres at the top right corner of the photograph.

Table 1. Iron production sites in the wider archaeological landscape of Great Zimbabwe. The grey shade represents excavated sites.

Local Site Name	Geographical Coordinates	Researchers	Materials Description	Context of Location	Orientation Site	Nature of Technology
Mashava	20° 03' 54,00" S 30° 31' 46,00" E	Mtetwa, E.	Furnace rubble, iron ore, flow and furnace slags, fused and single tuyeres	Iron-ore fields, woodlands, no settlements, stream	West side of hill with iron-ore quarry on the east side of hill	Natural draft
Boroma	20° 16' 02,14" S 30° 58' 00,30" E	Mtetwa, E.	Furnace rubble, slag with bone inclusions, smithing slag, fused and single, iron hoe.	Woodlands, near village and stream.	West side of granite boulders	Natural draft
Morgenster Road	20° 17' 01,60" S 30° 55' 51,50" E	Mtetwa, E.	Chunky slag and tuyere fragments	Woodlands, near perennial stream	West of granite boulders	Forced draft
Mukungwa 1	20° 16' 47,60" S 30° 56' 35,00" E	Mtetwa, E.	Chunky iron smelting slag, furnace rubble, tuyere fragments	Woodlands, perennial natural spring, marshes	West of granite boulders	Forced draft
Mukungwa 2	20° 17' 00,00" S 30° 56' 19,30" E	Mtetwa, E.	Furnace slag and tuyere fragments	Woodlands and marshes	West of granite boulders	Forced draft
Mukungwa 3	20° 16' 55,00" S 30° 56' 24,80" E	Mtetwa, E.	Tap and furnace slag	Woodlands and streams	West of granite boulders	Forced draft
Nemanwa GP	20° 16' 20,50" S 30° 54' 50,80" E	Mtetwa, E.	Slag scatters and tuyere fragments	Woodlands	West of granite boulders	Uncertain
Veza A	20° 17' 46,60" S 30° 50' 29,90" E	Mtetwa, E.	Bulky vitrified furnace rubble, multiple fused & single tuyeres	Woodlands, iron-ore fields, perennial stream	West of granite whale-back, west-facing escarpment	Natural draft

Veza B	20° 18' 20,40" S 30° 50' 19,90" E	Mtetwa, E.	Bulky vitrified furnace walls, multiple fused & single tuyeres	Woodlands, iron-ore fields, perennial stream	West of granite boul- ders	Natural draft
Goose Bay	20° 13' 53,65" S 30° 59' 41,28" E	Collett, D. P. Mtetwa, E.	Single tuyeres, phallic ob- ject, crucible, house floor, decorated pottery	Woodlands, peren- nial river, within set- tlement	West of granite boul- ders	Forced draft
Great Zimbabwe 1	20° 16' 03,18" S 30° 56' 04,52" E	Bandama et al. Mtetwa, E.	Slag scatters	Within the Hill Com- plex	Surrounded by granite boulders all-round	Uncertain
Great Zimbabwe 2	20° 15' 54,07" S 30° 56' 04,52" E	Bandama et al. Mtetwa, E.	Slag scatters	Near the Eastern En- closure	West of granite boul- ders	Uncertain
Great Zimbabwe 3	20° 16' 02,68" S 30° 56' 04,52" E	Bandama et al. Mtetwa, E.	Slag scatters	Near the Eastern En- closure	West of granite boul- ders	Uncertain
Great Zimbabwe 4	20° 16' 11,39" S 30° 55' 58,44" E	Bandama et al. Mtetwa, E.	Slag scatters	Terraced Hill	East of Site Museum Hill	Uncertain
Great Zimbabwe 5	20° 15' 40,00" S 30° 55' 43,25" E	Bandama et al. Mtetwa, E.	Slag scatters	Open space	On top of whaleback hill	Uncertain
Great Zimbabwe 6	20° 15' 29,60" S 30° 55' 59,80" E	Mtetwa, E	Slag with bone inclusion	Woodlands and pe- rennial stream	West of anthill	Uncertain

Mutevedzi B.C.	20° 18' 13,30" S 30° 52' 50,00" E	Mtetwa, E.	Cluster of fused and single tuyeres, furnace rubble, slag with grass impressions	Woodlands, perennial stream,	Narrow gap in between two granite hills	Natural draft
Nezvigaro	20° 18' 16,10" S 30° 52' 50,00" E	Mtetwa, E.	Cluster of fused and single tuyeres, furnace rubble, slag with grass impressions	Woodlands, iron-ore fields, perennial stream	West of granite boulders	Natural draft
Chikwira 1	20° 19' 55,02" S 30° 47' 16,08" E	Mtetwa, E.	Fused tuyeres, furnace rubble, slags	Woodlands, iron-ore fields, in the hills	West of granite boulders	Natural draft
Chikwira 2	20° 20' 07,08" S 30° 47' 24,78" E	Mtetwa, E.	Furnace rubble, fused and single tuyeres, circular furnace bases	Woodlands, iron-ore fields, in the hills	West of granite whale-back	Natural draft
Chigaramboni 1	20° 18' 30,46" S 30° 28' 11,68" E	Ndoro, W. Mtetwa, E.	Furnace rubble, fused & single tuyeres, chunks of slag	Woodlands, iron-ore fields, water-course	Western edge of hill	Natural draft
Chigaramboni 2	20° 20' 53,02" S 30° 46' 06,06" E	Ndoro, W. Mtetwa, E	Furnace bases, rubble, slag, fused and single tuyeres	Woodlands, iron-ore fields, water-course	West side of hill	Natural draft
Chigaramboni 3	20° 20' 30,30" S 30° 46' 30,94" E	Ndoro, W. Mtetwa, E	Furnace rubble, slag, fused and single tuyeres	Woodlands, iron-ore fields	Western edge of hill	Natural draft
Chigaramboni 4	20° 19' 56,03" S 30° 46' 23,52" E	Ndoro, W. Mtetwa, E	Furnace rubble, slag, single tuyeres	Woodland, Iron-ore fields, water-course	Open field	Forced draft
Chigaramboni 5	20° 20' 24,14" S 30° 46' 44,47" E	Ndoro, W. Mtetwa, E	Single tuyere fragments and slag	Woodlands, iron-ore fields	Open field	Forced draft
Chigaramboni 6	20° 20' 12,70" S 30° 46' 54,34" E	Ndoro, W. Mtetwa, E	Fused tuyere fragments and slag	Woodlands, iron-ore fields	West and at the foot of hill overlooking stream	Natural draft
Chigaramboni 7	20° 19' 50,56" S 30° 46' 58,40" E	Ndoro, W. Mtetwa, E	Furnace bases, rubble, slag, fused and single tuyeres	Woodlands, iron-ore fields	Western edge of hill	Natural draft

Chigaramboni 8	20° 19' 56,57" S 30° 49' 27,78" E	Ndoro, W. Mtetwa, E	Furnace bases, rubble, slag, fused and single tuy- eres	Woodlands, iron-ore fields	Western edge of hill	Natural draft
Chigaramboni 9	20° 02' 06,94" S 30° 47' 44,12" E	Ndoro, W. Mtetwa, E	Furnace bases, rubble, slag, fused and single tuy- eres	Woodlands, iron-ore, water-course	Western edge of hill	Natural draft
Chigaramboni 10	20° 20' 00,56" S 30° 47' 44,12" E	Ndoro, W. Mtetwa, E	Furnace bases, rubble, slag, fused and single tuy- eres	Woodlands, iron-ore, perennial stream	West side of hill	Natural draft
Chigaramboni 11	20° 19' 50,59" S 30° 47' 43,48" E	Ndoro, W. Mtetwa, E	Furnace bases, rubble, slag, fused and single tuy- eres	Woodlands and marshes	Western edge of hill	Natural draft
Chigaramboni 12	20° 20' 01,18" S 30° 47' 55,10" E	Mtetwa, E.	Furnace bases, rubble, slags, fused and single tuy- eres	Woodlands and marshes	Western edge of hill	Natural draft
Chigaramboni 13	20° 20' 13,67" S 30° 48' 12,06" E	Mtetwa, E.	Multiple fused tuyeres, slags and furnace rubble	Woodlands, iron-ore fields	West side of granite boulders	Natural draft
Chigaramboni 14	20° 19' 37,45" S 30° 46' 13,01" E	Mtetwa, E.	Multiple fused tuyeres, furnace rubble and slag	Woodlands and iron- ore fields	Western edge of hill	Natural draft
Chigaramboni 15	20° 19' 18,41" S 30° 46' 13,01" E	Mtetwa, E.	Fused and single tuyeres, slags	Woodlands, iron-ore and watercourse	West side of hill	Natural draft
Murazvo	20° 17' 06,40" S 30° 51' 33,90" E	Mtetwa, E.	Fused tuyeres, slags, blocky furnace rubble	Woodlands, peren- nial stream	West-facing escarp- ment	Natural draft
Cheshumba	20° 19' 18,41" S 30° 47' 30,08" E	Mtetwa, E.	Funnel shaped single tuy- eres, flags, furnace rubble	Woodlands, peren- nial stream	West side of anthill	Forced draft
Sviba 1	20° 17' 06,40" S 30° 51' 33,90" E	Mtetwa, E.	Fused and single tuyeres	Woodlands, marshes	In-between granite boulders below west of a high hill	Natural draft

Sviba 2	20° 17' 06,00" S	Mtetwa, E.	Furnace fragments and slags	Woodlands and marshes	At the foot and west of high	Uncertain
	30° 51' 21,10" E					
Sviba 3	20° 15' 42,10" S	Mtetwa, E.	Funneled and thick tuyere, chunky furnace slag with straw impressions	Woodlands, marshes	At the foot and west of high hill	Forced draft
	30° 58' 33,60" E					

3.3 Archaeometallurgy

Archaeometallurgy combines materials science, social archaeology and material culture studies to answer archaeological questions regarding the production and use of metals in past societies (Buchwald, 2005; Chirikure 2015; Killick and Fenn, 2012; Pleiner, 2000; Rehren, 2000; Roberts and Thornton, 2014). Archaeometallurgical methods may give information on technological choices, opportunities and constraints (Chirikure 2005, Rehren et al. 2007). The study is based on selected iron production debris such as slags, tuyere fragments, pieces of bloom and possible iron ores recovered from the areas surrounding the Great Zimbabwe urban centre. Below I summarize the materials and methods adopted in this study.

3.3.1 Visual and Macroscopic observations

The first level of archaeometallurgical analyses involved the visual and macroscopic examination of furnace blocks, tuyere pieces, varied types of slags, possible mineral ores and piece of iron bloom (e.g. Bayley et al 2001; Chirikure 2005; Greenfield and Miller 2004; Mapunda 1995). I used a physical attributes analysis schedule developed by Bertram Mapunda (1995), which enabled the initial classification of materials and interpretation of metallurgical processes as outlined in detail in Paper III. Much of this type of analysis was conducted in the field where such features as furnaces, large numbers of tuyeres and heaps of slags were examined in situ and reburied for further research.

3.3.2 Microscopic and chemical analyses of slags and piece of iron bloom

The second level of analysis involving laboratory techniques focused on the chemistry and microstructure of slags. The selected slag samples were exported to Sweden for examination at the Geoarkeologiska Laboratorium (GAL) Uppsala, where I also received training in archaeometallurgy. Some of the samples were sent to Axinit in Bratislava, Slovakia, for the production of polished thin sections and the microstructure was analysed using optical microscopy. Major chemical and trace elements were measured in 14 iron slag samples using ICP-AES and ICP-MS (see Paper IV for more details). Identification of mineralogical phases present in the analyzed slags was carried out on the polished thin sections. I used a Zeiss Axioskop 40A polarization microscope (up to 500x) to view the polished sections for slags at the GAL.

A possible piece of iron bloom was sectioned and polished for metallographic analysis at the GAL. This involved grinding the sample on a polishing machine using silicon carbide papers (120-1200 grit) first before a 1µm finish using a Diaduo paste. The microstructure of the sample was analysed under a

Zeiss Axioskop 40A polarization microscope at magnifications up to 500x equipped with an integrated digital camera (Zeiss AxioCam MRc5). Determination of the type of iron involved etching the polished block using 2% nitric acid in alcohol and examining it under the microscope for the detection of carbon. The amount of carbon present in a sample is what determines whether a piece of metal is cast iron, steel or wrought iron.

3.4 Archaeometry of metallurgical ceramics

Archaeometry, as a science-based subdiscipline of archaeology, is primarily concerned with the physical and mechanical properties of material culture (Jones, 2004). It employs chemistry, physics and geology to address how people made, exchanged, used and discarded artefacts (e.g. Bandama et al., 2017; Tite, 2008). Tuyeres from varied sites around Great Zimbabwe were examined, as they are a rich resource for understanding specialized production of metallurgical ceramics in the past. Macroscopic attributes of tuyeres recovered from varied sites in Great Zimbabwe were examined based on shape, which is often diagnostic of the air supply mechanisms used to drive the iron smelting furnaces. In African iron metallurgy, tuyere form is also important as some are shaped to look like parts of the male reproductive organs, providing a window into understanding broader cultural values embedded in technology (e.g. Chirikure et al., 2009; Schmidt, 2009). A detailed study of selected tuyeres was carried out (see Paper V) and summarized below.

3.4.1 Materials and methods

The tuyeres materials subjected to laboratory analyses in this study were selected from the sites shown in Table 1 below.

Table 2. Tuyere materials from iron production sites around Great Zimbabwe subjected to archaeometrical analyses

Site Name	Sample ID	Sample Con-text	Thermal & Surface Condition	Color
Boroma	BOA1	Part of a single tuyere from inside furnace	Vitrified and free of slag traces	Greyish brown
Boroma	BOA2	Multiple fused	Vitrified and free of slag traces	Brick red
Mutevedzi	MUI1	Part of tuyere fused in multiples	No trace of slag	Reddish yellow
Mutevedzi	MUI2	A different tuyere fused with MUI1	2 mm layer of slag on the outside surface	Reddish yellow
Veza A	VEA1	Double fused tuyeres	Vitrified with droplets of slag on the external surface	Dark greyish brown
Veza B	VEA2	Double fused tuyeres	Extensively coated on the distal end	Reddish brown
Chigaramboni	CHI1	Part of tuyere fused in multiples	Vitrified and free of slag traces	Greyish brown
Chigaramboni	CHI2	Different part but same tuyere as CHI1	Vitrified and free of slag traces	Greyish brown

3.4.1.1 X-Ray Fluorescence

A Thermo Scientific portable (handheld) XRF analyser (h-XRF, Niton XL3t 970 GOLDD+), was used to measure X-ray fluorescence (XRF) on a freshly cut cross-section on slightly polished samples (see Paper V for details). The XRF method has highly accurate determinations for elements (Helfert & Böhme 2010; Helfert *et al.* 2011; Papmehl-Dufay *et al.* 2013), and is a non-destructive method. The analysis included the elements: Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Y, Zr, Nb, Mo, Pd, Ag, Cd, Sn, Sb, Ba, W, Au, Pb, Bi, Th and U. Elements in the range from Sodium (Na) and lighter cannot be detected by this method. Analyses were performed on a freshly made cut on the cross section of the sherds.

3.4.1.2 Petrographic microscopy

Thin sections of 0.03 mm thickness were prepared. The coarseness of the paste, the amount of coarse silt, fine sand, medium sand, coarse sand and fine

gravel (ISO 14688-1:2002) was calculated under a polarising microscope using Nikon NIS Elements Br Imaging Software (ver. 3.10). The mineralogy of the sand fraction was determined through standard petrographic procedures.

3.4.1.3 Thermal analyses

The thermal properties of clays vary according to their composition, i.e. the type of clay minerals in question, the presence of oxyhydroxides of iron, calcite, fluxing ions (Na, K, Ca and Mg), amount of primary quartz and feldspar, coarse fraction etc. In order to study the variations in the thermal properties, analyses by means of the Thermal Colour Test (TCT) and the sintering interval have been performed (Hulthén 1976, Lindahl 1985). Statistical calculations were performed using IBM SPSS Ver.24.

3.5 Archaeobotany – an anthracological approach

Wood resources are crucial in iron technology both for technological innovation and also varied ritual and social contexts (Iles, 2016; Lyaya, 2013; Mapunda, 2010). The appropriation of wood for metallurgical purposes in Great Zimbabwe is thought, by some, to have caused significant deterioration of the environment, contributing to its eventual collapse among other socio-political factors (Bannerman, 1982; Chikumbirike, 2014; Pikirayi, 2006). The dearth of a detailed vegetation history of the Great Zimbabwe area, has limited possibilities of both testing the degradation hypothesis and/or exploring wood selection and management in relation to iron technology. As part of the PhD project, I therefore undertook to explore possible selection and outtake of wood species for metallurgical purposes through woodcharcoal analyses. The method has been successfully applied in the reconstruction of the vegetation history and paleoclimates of some locations in South Africa such as Colwinton, Banowe and Ravenscraig (Tusenius, 1986), as well as for instance Boomplaas (Scholtz, 1986). Charcoal analyses has also been used for landscape reconstruction in southern Africa (February, E., & Van der Merwe 1992; Deacon et al 1983; Ekblom et al. 2014; Esterhuysen, A. B., & Mitchell 1996; Vogelsang, R., & Eichhorn 2011). In particular, anthracology has also been used to address iron metallurgy questions elsewhere in the continent (Schmidt 1994).

3.5.1 Material

An assemblage of 108 charcoal fragments, which originated from proper archaeological excavations at Boroma, Goose Bay and Veza 1 sites in the wider archaeological landscape of the Great Zimbabwe centre, were analyzed (Table 3). The charcoal samples were recovered through dry sieving.

Table 3. Archaeological charcoal from the Great Zimbabwe cultural landscape subjected to anthracological analysis

Site Name	Location	Context	Collection Method	Collector	Quantity
Boroma	20° 16' 02,14" S 30° 58' 00,30" E	Iron smelting site	Excavation	Ezekia Mtetwa 2013	82
Goose Bay	20° 13' 53,65" S 30° 59' 41,28" E	Iron smelting site	Excavation	David Coll-ett 1986	13
Veza 1	20° 17' 46,60" S 30° 50' 29,90" E	Iron smelting site	Excavation	Ezekia Mtetwa 2014	33
TOTAL					108

3.5.2 Method

Dr. Joseph Chikumbirike, of School of Humanities, Sol Plaatje University, Kimberley, South Africa and an affiliate of the University of the Witwatersrand, School of Geography, Archaeology and Environmental Studies conducted the charcoal identification analysis. Charcoal fragments were manually snapped between the fingers into three different planes namely the transverse section (TS), the tangential longitudinal section (TLS) and radial longitudinal section (RLS). The specimens were identified using a Zeiss Stemi, high power Olympus BX51 petrographic microscope, and an Olympus SC30 camera with an Olympus Imaging Solutions Software for image analysis. The charcoal samples were analysed under a magnification of x50, x100 and x200. Wood identification was based on attributes as growth ring boundaries, wood porosity, vessels per square millimeter and parenchyma types. The type of rays (i.e. ray width, height, cellular composition, storied structure), fibres (septate fibre, fibres with simple pits), tracheids (vascular/vasicentric tracheids), and tyloses were used as a basis of identification.

4 Results

In this chapter, I present the results of the different data collection methods adopted in the study to illuminate the nature of iron production technologies present in the wider archaeological landscape of Great Zimbabwe. Examples of these results are presented here to provide the material basis of the specific discussions covered in the respective publication articles. First, I present evidence of technological variability as gleaned from written records, legacy collections and recent archaeological field surveys and excavations. The second section presents results from laboratory techniques for analyzing iron slags, a piece of possible iron bloom and tuyeres. In the last section, I present results of anthracological analysis of charcoal samples recovered during excavation of iron production sites around Great Zimbabwe. In the next chapter, I give a discussion of these results, which I interpret within the social agency and materiality theoretical frameworks.

4.1 Evidence from written records: smelting techniques, organization and ritual practices

The writings of both Carl Mauch and Theodore Bent, who visited the Great Zimbabwe area in the late 19th century AD, reveal that contemporary Shona communities made use of forced draft techniques to smelt iron in low shaft furnaces. Bellows made of goatskin were used to drive combustion air into the furnace through two openings at ground level, which according to Mauch, was sufficient to bring the ore to melting point (Burke and Mauch, 1969: 137). As a geologist, he also noted that the smelters exploited a chalk-slate containing ferruginous mica for iron ore, which they quarried from a local source, a walk of about 20 minutes. As part of thermal treatment, the smelters crushed the ores into small pieces before smelting them, a process they repeated over a period of between 5 to 8 days.

Apart from the drinking of beer to incentivize those pumping the bellows, Mauch did not report any ritual treatments of the furnaces because either he witnessed none, or the performances were there, but nothing worth recording. As reflected in Bent's writings, ritual performances were a common phenomenon in the indigenous iron metallurgy of many Shona subgroups in the late 19th and early 20th centuries AD (Bent, 1892), including many other societies

in Sub-Saharan Africa (Childs and Killick, 1993; Cline, 1937; Herbert, 1993; Schmidt, 2009; Terry Childs, 1991). I will deal with their implications in the discussion chapter in light of results from recent researches across the continent. Mauch did not also provide direct information regarding the roles of men and women in iron production activities, but since the reported smelting episode took outside the village, it is most likely that only men were present at the smelting site.

Another outcome from Mauch's eyewitness account critical for this study are the archaeometallurgical remains he reported of an earlier type of iron technology in the form of broken furnace rubble and broken clay tuyeres fused in doubles. Both Mauch and the local residents regarded these remains as belonging to an advanced iron technology, which they associated with an alleged white population that occupied the country in deep prehistory (Burke and Mauch, 1969: 136-137). Here the most important thing is that these remains indicate the presence of natural draft iron smelting technologies in the Great Zimbabwe area earlier on, contrasting sharply with the forced draft technology in use during Mauch's time. The two assemblages represented significant technological changes in the same area over time.

Bent's writings add more details to the results gleaned from Mauch's report above. Bent noted that the Shona communities in Chivi, about 30km west of Great Zimbabwe, also used low shaft forced-draft iron smelting techniques in the 1890s. He also observed that the Chivi furnaces were designed as a woman giving birth, the chimney being the head decorated invariably with eyes, nose and mouth, and breasts (Bent, 1892). Importantly, he noted that the smelters carried out ritual performances and observed restrictive taboos against female participation in the iron production process. Interestingly, the types of furnaces reported by the travelers have been corroborated by archaeological excavations at different sites in the Great Zimbabwe area such as Gokomere Mission (Ndoro, 1994; Sinclair, 1984) and around Zimbabwe (Bernhard, 1962; Cooke, 1959; Chirikure, 2006, 2005; McCosh, 1979). According to Prendergast (1979; 1974), the low shaft forced draft furnace was the most common type used by the Shona in the 19th century.

4.2 Existing Collections

The archaeometallurgical materials recovered in previous researches included three sites namely Goose Bay, Chigaramboni and Mashava. The funnel-shaped tuyere from Goose Bay suggest the use of forced-draft technology at the site. My examination of archaeometallurgical materials from Chigaramboni (Figure 4) identified large blocks of furnace rubble, tuyeres fused in multiples, and large and dense slags. Field photographs also show a very dense cluster of tuyeres in the excavation trench (Figure 5).

My own rescue excavations at Mashava ironworking site in 2010 revealed iron production debris at the site including about twenty possible furnace features, massive and dense slag and heaps of tuyeres (Mtetwa, 2011). Some of the slag pieces at the site are tuyere-moulded (Figure 5), showing the cylindrical shape of the tuyeres into which the molten slag flowed and solidified. Other slag pieces show a clear flow texture in the form of wrinkled red-brown surfaces and sand impression underneath (see Paper 1), which typically indicates slag tapping practices (Killick 1990; Chirikure and Rehren 2006a; Miller and Killick 2004). The concentration of furnace bases at this site represents large-scale iron production suggestive of a market beyond subsistence consumption.

4.3 Evidence from archaeological field surveys and excavations

Twenty-six new iron-working sites and fifteen others from previous archaeological surveys were recorded around the Great Zimbabwe urban centre (Table 1 in Paper 1). The majority of these sites had double fused tuyeres, some with as many as ten tuyeres fused together by slag (Paper 1). Almost all of the iron working sites were found located on the west side of granite landscape features such as whale-backed hills, bornhardts, kopjes and tors, and anthills in some cases, a behavior noted among the Tumbuka of central western Malawi (Killick, 1990) and Fipa of southwestern Tanzania (Mapunda, 2010). Humans are known to be creatures of culturally patterned behaviour (Hodder and Orton, 1976), and as I shall argue later in the discussion, the recurrent location of iron production activities west of boulders and anthills would have been both symbolical and practical (see also Mapunda, 1995).

Figure 8. A dense concentration of tuyeres in the excavation trench at Chigaramboni iron production site. Note that the frame is one square metre. (Photo by Webber Ndoro, 1991)

Figure 9. Tuyere-moulded slag from Mashava iron production site (Photo by author, 2015)

4.3.1 Boroma Excavations

The excavations at Boroma Site recovered iron slag, broken tuyere pieces, furnace rubble, and charcoals. The bulk of slag from the Trench 2 was made up of large cake-like blocks, the largest one measured about 15 x 13 cm, and a thickness of about 7 cm, suggesting that these were furnace slag. Some of these blocks had plant impressions and possible bone inclusions. Trench 3 yielded small slag pieces of amorphous shape measuring 3 x 2 cm on average. The slag had very low magnetism and was very porous. At least 30 broken tuyere pieces measuring at most 15 cm in length were recovered from Trench 2. A maximum of four broken tuyere pieces were found fused together, suggesting that the smelting process used natural draft air-supply mechanism (Figure 8). Both single and multiple-fused tuyere exhibited evidence of vitrification and collapse at the distal end, indicating that these were inserted deep into the furnace where they were affected by very high temperatures. The internal diameter of the different tuyere recovered at Boroma site ranged between 30 and 40 cm, while their external diameter measured between 50 and 60 cm.

Figure 10. Boroma excavation archaeometallurgical materials: Multiple fused tuyeres (left); Plant impressed slag (right) Photo by author, Field Data (2013)

4.3.2 Veza 1 Excavations

A semi-circular furnace wall measuring 100 cm in diameter, with a plastered base tilting gently westwards was uncovered in association with multiple fused and a single tuyere. The western section of the furnace wall had been totally removed, probably by the ancient metallurgists themselves as a way of harvesting the bloom from the furnace chamber. A possible rake channel was also uncovered sloping down to the west from the furnace and continuing beyond the main trench, which necessitated an extension on the southwestern corner measuring 1x1m. This structure measured about 50 cm wide and at least 120 cm long. Charcoal samples were collected from a cluster of tuyeres on the floor of the furnace for purposes of radiocarbon dating and wood species identification. The tuyeres had an average internal diameter of about

3.5cm, a wall thickness of about 1.5 cm and length of about 20 cm. At least two tuyeres were found fused together with evidence of vitrification and melting at the distal end, indicating that they were exposed to very high temperatures deep inside the furnace during the smelting process. The excavations also yielded possible smithing slag characterized by plano-convex shape, co-existing with smelting slag in the same locality.

4.3.3 Mutevedzi Excavations

A rectangular furnace base was uncovered in association with at least twenty tuyere was uncovered. The furnace wall, which was about 15 cm thick, had visible finger impressions, vitrification evidence of possible leakage. The floor of the furnace sloped gently northwards and the southern end of the furnace was destroyed. The furnace base, which measured about 2 x 1 showed evidence of slag leakage through the cracks in its 10 cm thick wall. The rectangular furnace base is a unique design discovered at Mutevedzi site. It is unclear whether this furnace was once similar to the one described under Veza 1 above. At least 20 tuyeres were found arranged by the side of the furnace base as if kept for recycling. Almost all of the tuyeres had signs of vitrification with an average length of 25cm. At least three tuyeres were found fused together, showing signs of total collapse and melting on the end closest to the fire bed (Figure 10). The slag recovered from the excavation had very high porosity and straw impressions, with some of them exhibiting near-straight edges from the shape of the furnace. The slag had very low magnetism.

Figure 11. Archaeometallurgical Remains from Mutevedzi Site: Tuyeres fused in multiples (left); Plant impressed slag with straight edge. Photo by author, Field Data (2014)

4.4 Results for chemical and microstructural analyses

The detailed archaeometallurgical results are given in Paper II, and here I give a condensed summary.

4.4.1 Mashava

The bulk chemical composition analyses reveal a low average content of iron oxide (57 wt%), a very high content of silica (38 wt%) and as low as 3.6 wt% alumina for samples Mas1 and Mas2, relative to the range established for bloomery iron technology (Morton and Wingrove, 1969). Such a low iron oxide content commonly indicates an efficient iron smelting process (Iles and Martín-Torres, 2009), while the low amount of alumina underpins that the sample originated from tap slag. This confirms the flow structure observed during macroscopic examination of the two samples. The observed high silica levels silica content usually indicates a deliberate addition of sand to slag-metal separation particularly for high grade iron ore such as magnetite (e.g. Killick and Miller, 2014). Microstructurally, slag samples from Mashava site are distinct, characterized by well-crystallized and very fine-skeletal fayalite grains in a glassy matrix and angular magnetite, which further supports the observation that this is tap slag. Again, sample Mas1 has evidence of a bright continuous line of magnetite, which forms when slag cools and crystallizes rapidly in oxidizing conditions outside the furnace (see Figure in Paper IV). Slag tapping techniques is considered a novel process in preindustrial iron metallurgy, which made it possible to smelt the ore for longer periods without blocking the flow of combustion air through the tuyeres into the furnace. The slags are also constituted by well-crystallized fayalite, representing well-controlled reducing conditions and intense heat capable of transforming as much iron ores as possible into metallic iron (Buchwald, 2005).

4.4.2 Mutevedzi

The results for the chemical analysis of Mutevedzi slag reveal that it has the lowest content of iron oxide (about 43 wt%), the highest level of manganese oxide (almost 12 wt%) and a relatively high silica content (26 wt%), as shown in Table 3 in Paper II. It also has as high 8 wt% alumina content, more than 3 wt% calcium oxide, the highest reading in of all the analysed samples in this study, and has more than 2 wt% magnesium and potassium oxides. As commonly encountered elsewhere, slags with such a high content in manganese oxide often indicate an efficient slag-metal separation process (Chirikure and Rehren, 2006a; Iles, 2014; Pleiner, 2000). Charlton et al. (2010: 353) explain that non-ferrous oxides such as manganese and calcium tend to substitute iron oxide as a flux for silica, which improves the yield of metallic iron. They also note that amounts of alumina above 5 wt% often increases a slag's melting

temperature and viscosity. Mutevedzi slag has very little wüstite in its microstructure characterized by the predominance of fayalite and wüstite. In sum, both the slag chemistry and microstructure of Mutevedzi reveal a high level of skill in the past metallurgists in manipulating bloomery recipes and processes. Interestingly Mashava slag samples have the lowest manganese content (0.43 wt%), indicating significant variations in the technological approaches used at Mutevedzi, whose slags show no evidence tap slag.

4.4.3 Boroma

Boroma slag is chemically and microstructurally related to Mutevedzi than Mashava particularly sample Bor2 with as low as 55 wt% iron oxide as high as 11.7 wt% manganese oxide (see Table 3 in Paper IV). There is also a noticeable amount of alumina in all the three samples analysed, more than 5 wt%. The microstructure of the samples is dominated by fayalite, leucite and hercynite, very few iron prills and a small amount of wüstite. As observed and explained under Mutevedzi above, the high content of manganese and alumina in the slag samples indicate that these oxides would have been critical in achieving an efficient slag-metal reaction process and the formation of molten slag. According to Smedley et al. (2001) and Stern et al. (2004), wood selected for metallurgical purposes are at times rich in lime, potash and magnesia and manganese having taken these minerals from a habitat and geology rich in such elements. While this may be true for the other elements, the manganese levels in the slag samples of Boroma and Mutevedzi sites are too high to be explained in this way. It is most likely that smelters at the two sites exploited a manganese rich iron ore or fluxes as suggested by Iles (2014) and Pleiner (2000), which would explain their difference with Mashava site, where magnetite was presumably smelted (Mtetwa, 2011).

4.4.4 Sviba

The dominant chemical elements in Sviba slag are iron oxide (about 67 wt%), silica (25 wt%) and alumina (about 6 wt%). All the other oxides are below 1 wt%, revealing a significant difference from the slag chemistry of Mashava, Mutevedzi and Boroma above. Its microstructure of the slag reflects a mineralogical composition characterized by a dominant fayalite phase, dendritic wüstite and hercynite and subordinate leucite (see Figure in Paper II). The absence of noticeable trace elements in Sviba slag suggests that the smelters at the site may have added no fluxing materials into furnace. Rather, the smelters would have relied, most likely, on clays rich in silica or intentionally mixed with sand to make furnace lining and tuyeres to survive as both refractory materials and sacrificed in slag formation, a practice commonly encountered in preindustrial iron metallurgy (Chirikure, 2015; Veldhuzen and Rehren, 2014). In such situations, as noted by (Charlton et al., 2010), silica reacts with iron oxide to

form a ferrosilicate slag at temperatures above 1200°C, a process that enhanced the slagging process, but reduced the yield of metallic iron. This is a reasonable explanation for the relatively high content of iron oxide, silica and alumina observed in the slag chemistry of Sviba site, with alumina being critical for increasing the melting temperature and viscosity of the slag.

4.4.5 Veza A Site

Two samples, VezA1 and VezA2, were analysed from Veza A site. The chemical analysis result for sample VezA1 reveal a considerably high content of iron oxide (71 wt%), and a relatively low amount of silica (17 wt%) and alumina (3.5 wt%). With the exception of magnesium and calcium oxides, which have around 1 wt%, all the other oxides namely titanium, manganese, magnesium, calcium, sodium, potassium and phosphorus are below 1 wt%. The high amount of iron oxide is also reflected in the microstructure of the sample in the form of dendritic wustite. There are also remnants of the metallic iron in the microstructure, which explains why the sample is magnetic (see macroscopic attributes in Table 2 and the photomicrograph in Figure in Paper II). The microstructure also reveals blocky fayalite indicative of slow cooling of the slag in non-oxidizing conditions inside the furnace, which confirms the sample as a piece of iron smelting slag. However, sample VezA2, which has a plano-convex morphology macroscopically, has a higher iron oxide content of 76 wt%, very low silica content of 9 wt% and alumina content as little as 2 wt%, which classifies it as smithing slag (see Serneels and Perret, 2003). This is a reasonable conclusion, given that there is no further contribution of silica from furnace lining and tuyeres in a smithing in hearth, which is usually an open fireplace. The presence of smelting and smithing slag at Veza 1 provides a crucial window into understanding variation and change in the spatial organization of technology, a point that I will pick for elaboration in the discussion chapter.

4.4.6 Veza B Site

Although this site is located barely 2 kilometres away from Veza A along the same stream, it has a distinct chemical composition and microstructure. Chemically, sample VezB1 has an iron oxide content of 66 wt%, silica content of 17 wt %, about 4 wt% of alumina and a noteworthy 5 wt% manganese. The chemical results also reveal a noticeable presence of such oxides as magnesium, calcium and potassium above 1 wt%, which are usually introduced into the smelt from the fuel ash, as observed elsewhere (Chirikure, 2005; Smedley et al., 2001; Stern et al., 2004). The low levels of alumina in the sample suggest the possible use of slag tapping techniques at the site as observed at Baranda site in northern Zimbabwe (see Chirikure and Rehren, 2006). However, the absence of well-crystallized and very fine-skeletal fayalite grains in the microstructure of Veza 2 slag makes such a possibility very unlikely. The

mineralogical composition shows a high presence of wustite, fayalite, glass, leucite as well as droplets of metallic iron.

4.4.7 Chigaramboni

Two samples were analysed from Chigaramboni site, Chi1 and Chi2. The chemical composition of Chi1 is dominated by iron oxide (c. 67 wt%), silica (c. 20 wt%), manganese (c. 7 wt%) and alumina (c. 5 wt%). The sample is also composed of noticeable amounts of magnesium (c. 2 wt%), calcium (c. 3 wt%) and potassium (2 wt%). As noted under Mutevedzi, Boroma and Veza B sites, the enriched levels of manganese mostly derive from the type of ore exploited at these sites. Similarly, alumina would have increased slag's melting temperature and viscosity, as explained by (Charlton et al., 2010). The tendency for manganese to enhance the slag-metal separation process means that such an ore would have preferred ahead of other options, which raises questions regarding the politics of inclusion and exclusion from access among contemporary users, a discussion that I will return to in the next chapter. Such elements such as calcium and potassium usually derive from fuel ash, and there seems to be a set of particular trees that produce such fuel ash, which possibly made them coveted resources. The microstructure of Chi1 is dominated by fayalite, dendritic wustite and droplets of metallic iron, which explains why the slag is magnetic, among other physical properties highlighted in Table 3 in Paper II.

Sample Chi2, on the other hand, has the second highest content of iron oxide (c. 91 wt%), and the lowest amount of silica (c. 5 wt%), alumina (c. 1 wt%), a noticeably high content of manganese (c. 4 wt%) and magnesium (c. 2 wt%). All the other elements fall far below 1 wt%. Its microstructure shows a complex combination of wustite-magnetite and interstitial glass. A wustite-magnetite combination suggests that this sample derived from furnace slag, which was close to the mouth of tuyeres where it cooled under partially oxidizing conditions.

4.4.8 Goose Bay

The chemical result for Goose Bay slag reveals the highest content of iron oxide (c. 95 wt%) and very low silica (c. 8 wt%) and alumina (c. 3 wt%). The rest of the elements analysed in this study for Goo1 are far below 1 wt%. Its microstructure shows blocky fayalite, dendritic wustite and interstitial glass. The blocky fayalite suggests that this sample derived from furnace slag. The high iron oxide suggests that the slag-metal separation process was not very efficient, most likely because of very little silica and alumina. As observed at the other sites, silica is crucial for the slagging process, while alumina is equally essential for increasing the slag's melting temperature (Buchwald, 2005; Charlton et al., 2010). Macrophysically, Goo1 is dense, heavy and has

a metallic grey streak all around the sample, with one of its sides being moderately magnetic.

4.5 Evidence from Anthracological analysis

The aim of the anthracological analysis was to identify all the studied fragments to the level of their species. This data has not been presented elsewhere and therefore I will detail the result here. At least five taxa made up the species diversity of trees selected in the iron production activities largely for wood charcoal fuel and possible technomedicines. These include *Dichrostachys cinerea*, *Julbernardia globiflora*, *Brachystegia*, *Acacia* and an unidentifiable one. The iron smelters at Boroma site seem to have exploited all the identified taxa, with the exception of the *Brachystegia* genus, which is missing in the assemblage. *Acacia polyacantha* occurs at two of the three sites that yielded is the commonest taxa, followed by *Dichrostachys cinerea*. Boroma is the only site showing the occurrence of *Julbernardia globiflora* while Veza A is the only one with the *Brachystegia* genus. Goose Bay is second in terms of species diversity, showing a bias towards *Dichrostachys cinerea* and *Acacia polyacantha*. The popularity of these two tree species in the iron industry of Boroma and Goose Bay sites is noteworthy, as shall be detailed in the following discussion chapter.

Table 4. Tree species identified from archaeological charcoals found in association with iron production sites around Great Zimbabwe

Site Name	Charcoal Samples	Number of Tree Species Identified	Identified Genus and Species
Boroma	82	3	<i>Dichrostachys cinerea</i> , <i>Julbernardia globiflora</i> and <i>Acacia</i>
Goose Bay	13	2	<i>Dichrostachys cinerea</i> and <i>Acacia</i> .
Veza A	33	1	<i>Brachystegia</i>

4.5.1 Boroma Site

Under reflected light microscopy, specimen 1 from Boroma Trench 2 showed ray cells that are crystallized and heterogeneous. The ray cells are also square, procumbent and upright. The parenchyma is 3 cells wide. Rays are 1-3 seriate. Radial multiples of 2-3 occur. Solitary vessel arrangement occurs as well. The specimen is however, predominantly radial multiple, which suggests that this is *Dichrostachys cinerea* (Figure 3A). As a species, *D. cinerea* has a wide range of uses. Because it burns slowly and well, it is a favorite of metalworkers as an excellent source of fuel (Palgrave 2002). Its roots and leaves are used to

treat snakebites and scorpion stings including sore eyes and toothaches (van Wyk and van Wyk 1997). Its hardness makes it perfect for tool handles such as axes, hoes and ceremonial spears. In ecological studies, the tree species is regarded as an indicator of overgrazing and impoverished ground (Drummond and Palgrave 1973; van Wyk and van Wyk 1997).

Specimen 2 from the same site and trench as specimen 1 above showed solitary vessel arrangement, rectilinear parenchyma, and banded parenchyma 2-4 cells wide under the microscope (Figure 3B). The rays are 2-5 lines, semi-ring porous and square to upright, mixed cells, Procumbent, TLS (E-F): 4; 5 cells wide, heterogeneous ray cells, pitted fibers, more than 4 cells wide, suggesting that this is *Acacia* species (see Chikumbirike 2014). This species produces wood of high density, about 800-890kg/m³ and makes excellent charcoal. Its firewood generates a lot of heat and burns very evenly and cleanly with little smoke a favourite of many families in southern African (Timberlake et al 1999). Like the other tree species, it was used in many other social contexts including medicine where traditional healers treat general body pains, dizziness, convulsions, diarrhoea and it is used as an aphrodisiac. In Zimbabwe, peasant farmers lace its roots in the chicken run to control parasites, while its barks are used to treat poisoned cattle (Chikumbirike 2014).

Figure 12. Photomicrograph of charcoal specimen from Boroma Site Trench 2: (A) shows the microstructure of *Dichrostachys cinerea*; (B) shows the microstructure of *Acacia* species; (C) shows *Julbernadia globiflora*. (Photo by Joseph Chikumbirike, 2017).

The analysis of specimen 3 from Boroma site, Trench 2 level 4, reflected 1-2 seriate and banded parenchyma. The vessel arrangement are solitary with radial multiples of 2 showing procumbent cells, while the rays are 1-3 cells wide and crystalliferous (see Figure 12C), suggesting that this is *Julbernardia globiflora*. This tree species occurs in miombo woodland alongside *Brachystegia spiciformis*. It is used as a general-purpose timber and for making mortars for crushing grains especially maize (Palgrave 2002).

4.5.2 Veza A Site

Under optical microscopy, the vessel arrangement of this specimen are exclusively solitary. The rays are uniseriates and its cells appear crystallized. There is a line of parenchyma, 7 vessels per square millimeter. It also exhibits a banded parenchyma. The rays are uniseriates and are 8 cells long. The specimen is identified as the family of Caesalpiniaceae and possibly the *Brachystegia* genus (see Figure 12). The *Brachystegia* genus is suitable for general-purpose timber and firewood (Chikumbirike 2014). Its roots are used as a medicine for treatment of dysentery and diarrhoea. Furthermore, a decoction is applied to the eyelashes to treat conjunctivitis, which reflects how trees were used in wide range of social contexts (van Wyk and van Wyk 1997).

4.5.3 Goose Bay Site

Charcoal samples from Goose Bay exhibited similarities with specimen 1 of Boroma site charcoal samples. Under reflected light microscopy, the specimen revealed radial multiples 2-3, confluent to banded parenchyma, rays are 1-3 ray lines, Aliform parenchyma. The TLS are 2 cells wide, have short vessels, and 3 wide heterogeneous ray cells. They also are square to procumbent on the margins, procumbent in the middle and inside the rays. Like the Boroma specimen (see Figure 12A), the specimen was identified as *Dichrostachys cinerea* (Figure 12B).

Figure 13. Photomicrograph of the charcoal specimen from Veza A identified as the family of Caesalpiniaceae and possibly the *Brachystegia* genus. (Photo by Joseph Chikumbirike, 2017).

5 Discussion

Here, I will summarize the results in relation to questions regarding the organization of technology, its variability as well as human-environment interactions raised in the introductory chapter.

5.1 Spatial and social organization

The results from both macroscopic and microscopic analyses show that the spatial organization of industrial activities in the wider archaeological landscape of Great Zimbabwe was more varied and ambiguous than previously asserted. Iron smelting, usually associated with ritual performances and the rhetoric of human procreation, is generally suggested to have taken place outside settlements in seclusion from women, children and strangers (e.g. Childs and Killick, 1993; Huffman, 2001, 1986). The co-existence of smelting and smithing slags at Veza A site, however, demonstrate that such rigid separation of these two activities in space was not always the case (see also Chirikure and Rehren, 2006). Interestingly, iron production debris from Boroma and Goose Bay sites underpin smelting and smithing activities within domestic contexts, as observed also in the Great Zimbabwe urban centre itself (see Bandama et al 2016; Fredriksen and Chirikure 2015; Herbert, 1996; Miller 2002).

The varied spatial organisation revealed suggests an intimate link between iron technology and the dynamics of social power relations amongst the Great Zimbabwe inhabitants. It has been assumed, previously, that the elite controlled iron production in the entire empire (Herbert, 1996). This notion projected the Great Zimbabwe society as a highly centralised society in which the rulers made decisions regarding the daily activities associated with the specialised production of artefacts and materials. I would argue, however, that the presence of archaeometallurgical remains within domestic contexts suggests the existence of independently organised production across the wider archaeological landscape of Great Zimbabwe. It suggests that technology was probably less controlled than once thought, and practiced across social groupings outside of elite control. Large-scale iron production activities were also observed outside settlement, e.g. at Mashava and Chigaramboni. Considering the observed technological variation in space and time, such large-scale production would have run under self-organized specialists who had the flexibility to

make decisions on iron related practices (see similar discussion in Hjärthner-Holder & Risberg 2009: 983). Indeed, such specialists would have paid tribute to the rulers for continued support of their activities (see Mudenge, 1988). Such tribute would have taken the form of finished iron products, raw materials or even labor, as suggested the cache of iron hoes, iron ore and varied other metal objects found at Great Zimbabwe (see detailed review in Chirikure and Pikirayi, 2008).

Furthermore, the location of iron production within the domestic arena provided a context in which women and possibly children would have been socialized into, or negotiated their way into the world of iron. Likewise, the existence of iron metallurgy in the domestic sphere also meant that there was a mutual influence with other social practices and worldviews as evidenced such decorations as female anatomical organs, which could be found also on houses, pots, drums and headrests (Chirikure, 2005; Collett, 1993). This way of viewing these decoration crossovers has the potential to provide an alternative reading of iron technology in which female agency is far more prominent than what has previously been realized. Within such household industries (DeMarrais, 2013; Hirth, 2009), iron production would have directly involved the collective effort of all able-bodied family members in all metallurgical activities ranging from gathering of raw materials to distribution of the iron metal.

The modern-day case of Mbuya Murozvi's home-based smithing activities dealt with in Paper IV is a classic example demonstrating how a female agent through social negotiation and appropriation of iron smelting became a chief smith within an industry largely viewed as a male domain. An inclusive involvement of varied social agents beyond the male gender in iron technology could be considered for the iron smelting activities located also outside settlements. Spatial variation does not necessarily suggest a different belief system between smelting inside and outside settlements (see discussion in Fredriksen and Chirikure 2015). The entire process of iron production is, in itself, is a collective enactment of materials and disparate esoteric knowledge and know-how, which are usually embodied in different individuals.

5.2 Technological variability

The results show the existence of a remarkable variety of iron production technologies that developed and changed over time. The area has concentrations of iron production sites intimately correlated with the mountain ranges surrounding the urban centre, illustrating the social and physical use of the landscape. These remains point to a wide range of novel designs and processes of metal extraction in the form of natural draft furnaces, tap slags and a rectangular furnace design previously unknown in the iron metallurgy of southern

Africa. The discovery of tap slag at Mashava site, confirmed by both macroscopic and microscopic analyses, has significantly advanced our knowledge of the technology and processes of iron production south of the Zambezi River.

In addition, there is now a growing corpus of evidence pointing to the use of natural draft iron smelting technologies at several sites in the form of tuyeres fused in multiples and large concentrations of wide furnace bases. The presence of large natural draft furnaces in the Chigaramboni hills, Mashava, Boroma, Mutevedzi and Veza sites represents a significant change in technology intimately linked to transformations in the social, economic and environmental systems and processes of Great Zimbabwe. The large capacity of natural draft furnaces, for instance, point to the existence of large-scale trade in improved quantities and quality of iron at the zenith of intensified links with the Indian Ocean trade community (see similar discussion in Cline, 1937). As such, it would seem more likely that the coveted iron from the interior of southern Africa traded along the Mozambican Coast during Al Idrisi's visit in 1154 derived from the iron industry of Great Zimbabwe.

Interestingly, two sites with tuyeres fused in multiples have been radiocarbon dated to the early second millennium AD, making Great Zimbabwe one of the earliest known areas with evidence of natural draft technology in southern Africa (for other examples see Chirikure and Rehren, 2006b; Prendergast, 1979). As such, the dates offer a new chronological frame to rethink the distribution and circumstances surrounding the development of natural draft technology in Sub-Saharan Africa. Proximity to the urban centre and dating suggest linkages with the metal extraction strategies of Great Zimbabwe itself, which was at its peak between the 12th and 16th centuries AD. So far, the use of huge natural draft furnaces in the technological history of the world's pre-modern societies is considered a possible independent invention in sub-Saharan Africa. The furnaces, driven by air sucked in at the base as buoyant hot air rises through the chimney (Rehder, 2000), freed much human labor from the pumping of bellows, which represents a significant mechanical and social advantage over forced draft technology. Apart from consuming large volumes of charcoal, the long smelting hours in natural draft furnaces also promoted the diffusion of carbon into iron, which would have produced high-quality steel blooms (see Cline, 1937; Killick, 2015, 1991).

Thus, there is a new emerging understanding of iron production in and around Great Zimbabwe. More detailed fieldwork, however, is required specifically to recover more high quality material for chronometric dating and archaeometallurgical analyses. In particular, we still know very little regarding the chronology, distribution and circumstances leading to the use of a rectangular furnace design similar to that excavated at Mutevedzi. All historic rectilinear furnace designs are widely reported in southeast Asia (G Juleff, 2009; G. Juleff, 1996; Tabor et al., 2005), which raises questions regarding

possible cross-borrowing of technological ideas in trade and social interactions between Great Zimbabwe and other parts of the distant world. In addition, lead isotope and elemental analyses of metal objects and the geochemistry of the exploited iron ores (e.g. Ling et al., 2014), for instance, have the potential to yield insights into the connections and disconnections between the Great Zimbabwe urban centre and the metallurgical resources and technologies across its wider archaeological landscape. These methods have not been included in this thesis, but should be developed in the future.

5.3 Variation and change in resource exploitation patterns

The results of anthracological analysis, coupled with information solicited from village elders, bring out an intimate interaction between the Great Zimbabwe inhabitants and their biophysical environment. With an estimated population of about 10 000 inhabitants during its zenith period (see detailed review in Chirikure et al., 2017), Great Zimbabwe would have required vast amounts of wood resources for both domestic and metallurgical purposes. Its importance as a political and religious centre, and as the main interior hub of the Indian Ocean and Central African trade systems (Pikirayi, 2017) is likely to have resulted in an ever-increasing demand for improved quantities and quality of iron.

In Great Zimbabwe and many other places, the size and organization of production (Costin, 1991), was a key factor for the location of industrial activities. The large natural draft furnaces identified in the Great Zimbabwe area tended to be located away from settlements. One reason for this could be that the hinterland offered a variety of desired tree species and in larger quantities of charcoal fuel than closer to the center. In interviews with village elders living around Great Zimbabwe, residents stated that proximity to wood resources was usually the decisive factor in locating large-scale iron production activities. The logic behind was that, of all the raw materials required for iron smelting, wood charcoal was the bulkiest and most fragile, making charcoal impractical to transport it over long distances. Thus, the quantity and location of desired wood species was integral in shaping the social engagements between people and their material world in Great Zimbabwe. The discussion is relevant for our understanding of Great Zimbabwe environment. As reviewed in the introduction many researchers have argued that the environment around Great Zimbabwe became degraded over time. There are still no or little environmental data, however, to test this hypothesis.

Anthracological analysis carried out within the frames of this thesis has indicated that iron producers selectively exploited a range of tree species for the production of wood charcoal to fuel metallurgical processes (see summary

results section). Out of 149 tree species recorded from the modern flora in the Great Zimbabwe area by Chikumbirike (2014), four taxa namely *Dichrostachys cinerea*, *Julbernardia globiflora*, *Brachystegia*, *Acacia* have previously been identified as linked to the iron industry. From the charcoal assemblages presented here, the iron smelters at Boroma site seem to have exploited all the identified taxa, with the exception of the *Brachystegia* genus that is rare. *Acacia* occurs at two of the three sites that yielded is the commonest taxa, followed by *Dichrostachys cinerea*. Boroma is the only site showing the occurrence of *Julbernardia globiflora* while Veza A is the only one with the *Brachystegia* genus. The lack of *Brachystegia* on the sites analysed here could possibly suggest that this species was becoming increasingly rare due to exploitation. Amongst the *miombo* trees, *Julbernardia* appears to be favoured over *Brachystegia* with intensive exploitation (Ekblom et al in press). However, the charcoal analysis previously presented by Chikumbirike (2014), does not suggest temporal differences in selection of species. Thus, even though *Brachystegia* may have been locally rare or less preferred for iron production as may be suggested here, the changes observed by Bannerman (1982) with a near absence of both *Brachystegia* and *Julbernardia* must have been a late occurrence in history.

Apart from wood charcoal fuel and the iron ore itself, iron production also required flux materials for successful slag-metal separation. The slag chemistry of Boroma site, which exhibited close resemblances with that of Mutevedzi, Veza B and Chigaramboni (see Paper III), revealed enriched levels of such fuel ash oxides as calcium and potassium. These flux materials, possibly added as ritual medicines common in African iron metallurgy, point to the embeddedness of iron related practices in the efficacy of everyday belief systems (Schmidt, 2009a; Warnier, 2009). Calcium and potassium, which could have been provided from fuel ashes, but also bones, are good flux materials known for substituting iron oxide for silica, which improves the yield of metallic iron (Charlton et al., 2010). A block of slag from Boroma site, for instance, exhibited bone inclusions, which could have been deliberately charged into the furnace to decrease the melting temperature of the slag as part of the bloomery recipes, as evidenced elsewhere (De Caro et al., 2013; Prendergast, 1974; Summers, 1958). Thus, the iron technology of Great Zimbabwe, just like its drystone architecture which incorporated natural boulders into the wall fabric (Pikirayi, 2013), is characterized by an intimate social engagement between the people and their biophysical world.

The last but not least point to consider is the ever-growing interest regarding the possible effects of iron production on albedo and consequently on local climate (Ekblom et al, in press; Iles, 2016; Li et al., 2011; Schmidt, 1994). The discovery of natural draft furnaces in the Great Zimbabwe landscape during the course of this study adds further concern regarding the outtake of wood resources to meet the high demand for wood charcoal fuel in the iron industry. This realization is based on the point that although natural draft furnaces were

very economic in terms of labor, they are said to be expensive in fuel consumption (Killick 2015; 1991; 1990). The charcoal sample analysed in this study is rather small and from few sites to shed adequate light regarding this concern. It does suggest, however, the use of tree species indicative of significant changes in the nature and condition of the environment. The dominance of *Dichrostachys cinerea* as charcoal fuel in the analyzed sample, for instance, is understood in ecological studies as indicative of an opened landscape and forms secondary bush that grows in impoverished ground (see van Wyk and van Wyk 1997; Venter *et al.* 1996; Drummond and Palgrave 1973). Furthermore, there is a reduction in the number of tree species exploited at Goose Bay site, dated to the historical period, as compared to Boroma site dated to the early second millennium AD. It is not clear whether this reduction in tree species selected for use in the iron industry reflects environmental degradation or a matter of cultural choice during the period of Goose Bay Site. It would seem more likely that such a change in wood harvesting practices in the iron industry of Great Zimbabwe was in response to a modified environment. The importance of this study is that it indicates the effects of human-landscape interactions at a local scale.

6 Conclusion and future research

The results of this study shed significant and new light on varied aspects concerning the nature and organization of industrial activities that critically influenced and were equally influenced by the sociopolitical transformations of Great Zimbabwe over time. Importantly, they illuminate the role of ironworkers as crucial agents in establishing the social networks of places and other producers who were under the influence of Great Zimbabwe. These embodied social agents were critical in the production of social space and materials that shaped and were shaped by the everyday life experiences in Great Zimbabwe. The study's illumination of the iron metallurgy in the wider archaeological landscape also brings forward the intimate social engagements that would have sustained the urban itself in dynamic social networks.

Furthermore, the discovery of more evidence underpinning the widespread use of natural draft furnaces point to the existence of large-scale industrial iron production in Great Zimbabwe at some time in the past, at present one of the earliest known in Southern Africa. Contrary to earlier views, the range of archaeometallurgical material explored represent significant technological innovation and novel designs and processes of metal extraction in the form of slag tapping in further south of the Zambezi River in southern Africa. The iron production debris also suggests the co-existence of primary and secondary metal extraction in domestic and specialized settings outside settlements. These remains suggest varied scales of decentralized production involving household craft activities co-existing with the much large-scale industrial extraction of iron.

Within such decentralization, household production could point to internal trade amongst the inhabitants of the Great Zimbabwe area alongside large-scale production well adapted for extensive trade networks. Such household industries would have played a significant role in adapting to disconnections of the Great Zimbabwe state from global trade (Mtetwa, 1976; Pikirayi, 2017). Most importantly, the social memory of indigenous iron metallurgy curated within household industries continue to play a critical role in adapting to and surviving the collapse of Zimbabwe's economy since the dawn of the 21st century AD (Mtetwa et al 2016; Hjärthner-Holdar 1998).

Finally yet importantly, the study also illuminated how iron technology could also be appropriated to challenge gender roles. The domestic context of iron production would have provided a social space in which the control of

esoteric knowledge of iron technology would have been appropriated and negotiated across the gender and age axis. Using the case study of modern iron smithing near the Great Zimbabwe site, the study illustrated how a female chief negotiated her way into iron production usually viewed as a male domain. In so doing, the thesis brought forward the significance of iron in the large-scale social, economic, political and environmental systems and processes of Great Zimbabwe.

Although this study has illuminated significant aspects regarding the archaeologies of Great Zimbabwe's iron, there is need for further research. The lack of chronology for most of the studied iron production sites, for example, is a major weakness of this thesis. In the absence of dates, relative or chronometric, the only other variable suggestive of an association between the urban centre itself and sites in the hinterland is proximity. Proximity is a rather insecure link, seeing that metalworking communities have occupied the landscape around Great Zimbabwe from the early first millennium AD to the present. Any site can fall within that very broad range. Further excavations of industrial sites should strive to recover materials dateable by such methods as thermoluminescence. Again, chronology is very crucial to determine when the unique rectangular furnace, which was discovered during the course of this study, might have been introduced in the history of Great Zimbabwe.

There is also a need to conceptualize the newly illuminated iron technology of Great Zimbabwe within the broader context of connections and disconnections between southern Africa, the Indian Ocean and central African trade systems. So far, the archaeology of these technologies, which were critical in the production of the traded metals, have been treated independently (e.g. Chirikure 2005; Killick 1990; Mapunda 1995; Mtetwa 2011; in press). This downplays the possible inter-regional cross borrowing of technological expertise, ideas or even technicians over time and space. Such a research has the potential to shed significant light on the adaptation and adoption of metal technology within and beyond Africa. The existence of a rectangular furnace in the Great Zimbabwe landscape as reported in Paper I, requires comparative examination with similar structures in South-East Asia, a component of the Indian Ocean trade network community.

References

- Alpern, S.B., 2005. Did They or Didn't They Invent It? Iron in sub-Saharan Africa. *History in Africa*, 32(2005), pp.41–94.
- Armstrong, R. & Wilson, A.H., 2000. A SHRIMP U–Pb study of zircons from the layered sequence of the Great Dyke, Zimbabwe, and a granitoid anatectic dyke. *Earth and Planetary Science Letters*, 180(1–2), pp.1–12.
- Arthur, K.W., 2010. Feminine knowledge and skill reconsidered: Women and flaked stone tools. *American Anthropologist*, 112(2), pp.228–243.
- Bandama, F. et al., 2016. The Production, Distribution and Consumption of Metals and Alloys at Great Zimbabwe. *Archaeometry*, 58(S1), pp.164–181.
- Bandama, F., Moffett, A.J. & Chirikure, S., 2017. Typological and technological attributes of metallurgical crucibles from Great Zimbabwe (1000–1700 CE)'s legacy collections. *Journal of Archaeological Science: Reports*, 12(March), pp.646–657.
- Bannerman, J.H., 1982. Ecological And Other Factors In The Rise And Fall Of The Zimbabwe State.
- Bent, J.T., 1893. On the Finds at the Great Zimbabwe Ruins (with a View to Elucidating the Origin of the Race that Built Them). *The Journal of the Anthropological Institute of Great Britain and Ireland*, 22, pp.123–136.
- Bent, J.T., 1892. The ruins of Mashonaland, and explorations in the country. In *Proceedings of the Royal Geographical Society and Monthly Record of Geography*. JSTOR, pp. 273–298.
- Bernhard, F.O., 1962. Two Types of Iron-Smelting Furnaces on Ziwa Farm (Inyanga). *The South African Archaeological Bulletin*, 17(68), pp.235–236.
- Bourdieu, P., 1977. *Outline of a Social Practice*, Cambridge: Cambridge University Press.
- Brenan, J.P.M., Fernandes, A. & Wild, H. eds., 1968. *Flora Zambesiaca: Mozambique, Malawi, Zambia, Zimbabwe, Botswana. Supplement = Vegetation map of the Flora Zambesiaca region*, London.
- Buchwald, V.F., 2005. *Iron and steel in ancient times (Volume 29)*, The Royal Danish Academy of Sciences and Letters.
- Burke, E. & Mauch, K., 1969. *The Journals of Carl Mauch: his travels in the Transvaal and Rhodesia 1869-1872*, National Archives of Rhodesia.
- C. K. Cooke, 1959. An Iron Smelting-Site in the Matopo Hills, Southern Rhodesia. *The South African Archaeological Bulletin*, 14(55), pp.118–120.
- De Caro, T. et al., 2013. Archaeo-metallurgical studies of tuyeres and smelting slags found at Tharros (north-western Sardinia, Italy). *Applied Physics A: Materials Science and Processing*, 113(4), pp.933–943.
- Caton-Thompson, G., 1931. *The Zimbabwe culture: ruins and reactions*, Clarendon Press.
- Charlton, M.F. et al., 2010. Explaining the evolution of ironmaking recipes - An example from northwest Wales. *Journal of Anthropological Archaeology*, 29(3), pp.352–367.

- Chikumbirike, J., 2014. *Archaeological and palaeoecological implications of charcoal assemblages dated to the Holocene from Great Zimbabwe and its hinterland*. University of the Witwatersrand.
- Childs, S. T. and Killick, D., 1993. Indigenous African Metallurgy : Nature and Culture. *Annual Review of Anthropology*, 22(1993), pp.317–337.
- Childs, S.T. & Killick, D., 1993. Indigenous African metallurgy: nature and culture. *Annual Review of Anthropology*, 22, pp.317–337.
- Chipunza, K.T., 1994. *A diachronic analysis of the architecture of the Hill Complex at Great Zimbabwe*, Societas Archaeologica Upsaliensis.
- Chirikure, S. et al., 2016. Decisive Evidence for Multidirectional Evolution of Sociopolitical Complexity in Southern Africa. *African Archaeological Review*, 33(1), pp.75–95.
- Chirikure, S., 2005. Iron Production in Iron Age Zimbabwe : Thesis submitted to the University of London for the Degree of Doctor of Philosophy. , (August).
- Chirikure, S., 2015. *Metals in Past Societies: A Global Perspective on Indigenous African Metallurgy*, Springer.
- Chirikure, S., 2007a. Metals in society: Iron production and its position in Iron Age communities of southern Africa. *Journal of Social Archaeology*, 7(1), pp.72–100.
- Chirikure, S., 2007b. Metals in society: Iron production and its position in Iron Age communities of southern Africa. *Journal of Social Archaeology*, 7(1), pp.72–100.
- Chirikure, S., 2006. New light on Njanja iron working: Towards a systematic encounter between ethnohistory and archaeometallurgy. *South African Archaeological Bulletin*, 61(184), pp.142–151.
- Chirikure, S. et al., 2013. New Pathways of Sociopolitical Complexity in Southern Africa. *African Archaeological Review*, 30(4), pp.339–366.
- Chirikure, S. et al., 2017. What was the population of Great Zimbabwe (CE1000 – 1800)? , (Fig 1), pp.1–16.
- Chirikure, S., Burrett, R. & Heimann, R.B., 2009. Beyond furnaces and slags: a review study of bellows and their role in indigenous African metallurgical processes. *Azania: Archaeological research in Africa*, 44(2), pp.195–215.
- Chirikure, S. & Pikirayi, I., 2008. Inside and outside the dry stone walls: revisiting the material culture of Great Zimbabwe. *Antiquity*, 82(318), pp.976–993.
- Chirikure, S., Pwiti, G. & Pwiti, G., 2008. Community Involvement in Archaeology and Cultural Heritage Management: An Assessment from Case Studies in Southern Africa and elsewhere. *Current Anthropology*, 49(3), pp.467–485.
- Chirikure, S. & Rehren, T., 2006a. Iron smelting in pre-colonial Zimbabwe: Evidence for diachronic change from Swart village and Baranda, northern Zimbabwe. *Journal of African Archaeology*.
- Chirikure, S. & Rehren, T., 2006b. Iron smelting in pre-colonial Zimbabwe: Evidence for diachronic change from Swart village and Baranda, northern Zimbabwe. *Journal of African Archaeology*, 4(1), pp.37–54.
- Cline, W.B., 1937. *Mining and Metallurgy in Negro Africa*, Menasha, WI: George Banta.
- Collett, D.P., 1993. Metaphors and Representations of Precolonial Iron-Smelting in Eastern and Southern Africa. In A. Shaw, T; Sinclair; Andey, B. Okpoko, ed. *The Archaeology of Africa. Food MN'Metals and Towns*. London and New York: Routledge, pp. 499–511.
- Collett, D.P., Vines, A.E. & Hughes, E.G., 1992. The chronology of the Valley Enclosures: implications for the interpretation of Great Zimbabwe. *The African Archaeological Review*, 10(1), pp.139–161.

- Conkey, M., 1993. Humans as materialists and symbolists: Image-making in the upper paleolithic. *The origin and evolution of humans and humanness*, pp.95–118.
- Costin, C.L., 1991. Craft Specialization : Issues in Defining , Documenting , and Explaining. *Archaeological Method and Theory*, 3, pp.1–56.
- David, N. et al., 1989. Between bloomery and blast furnace: Mafa iron-smelting technology in North Cameroon. *The African Archaeological Review*, 7(1), pp.183–208.
- Deacon, H.J., Scholtz, A.&Daitz, L.D., 1983. Fossil charcoals as a source of palaeoecological information in the fynbos region. In Q. B. & Deacon, H. J., Hendey & J. J. N. Lambrechts, eds. *Fynbos palaeoecology: a preliminary synthesis. South African National Scientific Programmes Report 75:174-182*.
- DeMarrais, E., 2013. Understanding Heterarchy: Crafting and Social Projects in Pre-Hispanic Northwest Argentina. *Cambridge Archaeological Journal*, 23(3), pp.345–362.
- Dobres, A.M. et al., 1995. Gender and Prehistoric Technology : On the Social Agency of Technical Strategies Gender and prehistoric technology : on the social agency of technical strategies. *World Archaeology*, 27(1), pp.25–49.
- Dobres, M., 2000. *Technology and social agency: outlining a practice framework for archaeology*, Oxford: Blackwell.
- Eklblom, A. et al., 2014. Land use history and resource utilisation from a.d. 400 to the present, at Chibuenene, southern Mozambique. *Vegetation History and Archaeobotany*, 23(1), pp.15–32.
- Eklblom, A., 2012. Livelihood security, vulnerability and resilience: A historical analysis of Chibuenene, Southern Mozambique. *Ambio*, 41(5), pp.479–489.
- Eklblom, A. et al., 2012. Rainfall variability and vegetation dynamics of the lower Limpopo Valley, Southern Africa, 500AD to present. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 363–364, pp.69–78.
- Esterhuysen, A. B., & Mitchell, P.J., 1996. Palaeoenvironmental and archaeological implications of charcoal assemblages from Holocene sites in western Lesotho, southern Africa. *Palaeoecology of Africa*, 24, pp.203–232.
- February, E., & Van der Merwe, N.J., 1992. Stable carbon isotope ratios of wood charcoal during the past 4000 years: anthropogenic and climatic influences. *South African Journal of Science*, 88(5), p.291–292.
- Fontein, J., 2006. Silence, Destruction and Closure at Great Zimbabwe: Local Narratives of Desecration and Alienation. *Journal of Southern African Studies*, 32(4), pp.771–794.
- Fredriksen, P.D. & Chirikure, S., 2015. Beyond Static Models: An Evaluation of Present Status and Future Prospects for Iron Age Research in Southern Africa. *Cambridge Archaeological Journal*, 25(3), pp.597–614.
- Garlake, P.S., 1973. *Great Zimbabwe*, Stein & Day Pub.
- Garlake, P.S., 1982. *Great Zimbabwe*, Harare, Zimbabwe: Zimbabwe Pub. House.
- Garlake, P.S., 1978. Pastoralism and Zimbabwe. *The Journal of African History*, 19(4), pp.479–493.
- Giddens, A. (1984)., 1984. *The constitution of society: Outline of the theory of structuration*., Berkeley: University of California Press.
- Gwavava, O. & Ranganai, R.T., 2009. The Geology and Structure of the Masvingo Greenstone Belt and Adjacent Granite Plutons from Geophysical Data, Zimbabwe Craton. *South African Journal of Geology*, 112(3–4), pp.277–290.
- Hall, R.N., 1909. *Prehistoric Rhodesia: An Examination of the Historical, Ethnological and Archaeological Evidences as to the Origin and Age of the Rock Mines and Stone Buildings, with a Gazetteer of Medieval South-east Africa, 915 AD to 1760 AD, and the Countries of*, George W. Jacobs & Company.

- Hall, R.N., 1905. The Great Zimbabwe. *Journal of the Royal African Society*, 4(15), pp.295–300.
- Hedberg, I. & Hedberg, O., 1968. Conservation of vegetation in Africa south of the Sahara : proceedings of a symposium held at the 6th plenary meeting of the “Association pour l’étude taxonomique de la flore d’Afrique tropicale” (A.E.T.F.A.T.) in Uppsala, Sept. 12th-1.
- Hentze, K., Thonfeld, F. & Menz, G., 2016. Evaluating Crop Area Mapping from MODIS Time-Series as an Assessment Tool for Zimbabwe’s “Fast Track Land Reform Programme.”, pp.1–22.
- Herbert, E.W., 1993. *Iron, gender, and power: rituals of transformation in African societies*, Bloomington: Indiana University Press.
- Herbert, E.W., 1996. Metals and power at Great Zimbabwe. *Aspects of African archaeology*, pp.641–647.
- Hirth, K., 2009. Craft Production, Household Diversification, and Domestic Economy in Prehispanic Mesoamerica. *Archeological Papers of the American Anthropological Association*, 19(1), pp.13–32.
- Historical Metallurgy Society, 2008. *Metals and Metalworking: A research framework for archaeometallurgy*,
- Hjärthner-Holdar, E. & Risberg, C., 2009. Technology of Iron: Choices and Innovation. *Materials and Manufacturing Processes*, 24(9), pp.981–986.
- Hodder, I. and Orton, C., 1976. *Spatial analysis in archaeology*, Cambridge: Cambridge University Press.
- Holmgren, K. et al., 2012. Water-level variations in Lake Nhauhache, Mozambique, during the last 2,300 years. *Journal of Paleolimnology*, 48(2), pp.311–322.
- Huffman, T., 1978. The Iron Age of the Buhwa District , Rhodesia. *Occasional Papers of the National Museums and Monuments of Rhodesia*, 4(3), pp.81–111.
- Huffman, T.N., 1986. Cognitive studies of the Iron Age in Southern Africa. *World Archaeology*, 18(1), pp.84–95.
- Huffman, T.N., 2009. Mapungubwe and Great Zimbabwe: The origin and spread of social complexity in southern Africa. *Journal of Anthropological Archaeology*, 28(1), pp.37–54.
- Huffman, T.N., 1996. *Snakes and crocodiles: power and symbolism in ancient Zimbabwe*, Johannesburg: Witwatersrand UP.
- Huffman, T.N., 2014. Social Complexity in Southern Africa. *African Archaeological Review*, 32(1), pp.71–91.
- Huffman, T.N., 2001. The Central Cattle Pattern and interpreting the past. *Southern African Humanities*, 13, pp.19–35.
- Humphris, J.E., 2010. An archaeometallurgical investigation of iron smelting traditions in southern Rwanda. *Archaeology*, (March), pp.1–355.
- Iles, L., 2016. Iron Production in Uganda: Memories of a Near-forgotten Industry. In H. Orange, ed. *Reanimating Industrial Spaces: Conducting Memory Work in Post-industrial Societies*, 66., Routledge, pp. 158–175.
- Iles, L., 2014. The exploitation of manganese-rich “ore” to smelt iron in Mwenge, western Uganda, from the mid second millennium AD. *Journal of Archaeological Science*, 49(1), pp.423–441.
- Iles, L., 2016. The Role of Metallurgy in Transforming Global Forests. *Journal of Archaeological Method and Theory*, 23(4), pp.1219–1241.
- Iles, L. & Martínón-Torres, M., 2009. Pastoralist iron production on the Laikipia Plateau, Kenya: wider implications for archaeometallurgical studies. *Journal of Archaeological Science*, 36(10), pp.2314–2326.
- Jones, A., 2004. Archaeometry and materiality: materials based analysis in theory and practice. , 3(October 2003), pp.327–338.

- Jonsson, J., 1998. Early plant economy in Zimbabwe.
- Joyce, R.A. & Joyce, R.A., 2015. Materiality. , 26, pp.181–191.
- Juleff, G., 1996. An ancient wind-powered iron smelting technology in Sri Lanka. *Nature*, 379, pp.60–63.
- Juleff, G., 2009. Technology and evolution: a root and branch view of Asian iron from first-millenniumbc Sri Lanka to Japanese steel. *World Archaeology*, 41(4), pp.557–577.
- Kay, G., 1970. *Rhodesia: a human geography*, London: Univ. of London Press.
- Killick, D., 1991. A little-known extractive process: iron smelting in natural-draft furnaces. *JOM*, 43(4), pp.62–64.
- Killick, D., 2015. Invention and innovation in African iron-smelting technologies. *Cambridge Archaeological Journal*, 25(1), pp.307–319.
- Killick, D. & Fenn, T., 2012. Archaeometallurgy: The Study of Preindustrial Mining and Metallurgy. *Annual Review of Anthropology*, 41(1), pp.559–575. Available at: <http://dx.doi.org/10.1146/annurev-anthro-092611-145719>.
- Killick, D. & Miller, D., 2014. Smelting of magnetite and magnetite-ilmenite iron ores in the northern Lowveld, South Africa, ca. 1000 CE to ca. 1880 CE. *Journal of Archaeological Science*, 43(1), pp.239–255. Available at: http://uneau.summon.serialssolutions.com/2.0.0/link/0/eLvHCXMwIV3NbtQwELYQIIEgEKbhh9pDogDapb1TxLnCNuuKtEbIHGLJo6NWu1myzYBtae-A2_Ik-BxNrst6qEcX7IsJ57xzHhmvmEMCiucHdeIwhi_0UoolxWZwdyozLrQsWSDxrHB2P43eh-ysE6QMLW5DG92nKC11ZKUujXd_7iOFhCMWB8tSBOlXnKIXt60wjX9s.
- Killick, D.J., 1990. Technology in its social setting: the ironworkers of Kasungu, Malawi, 1860-1940. , pp.1860–1940.
- Kim, N.C. & Kusimba, C.M., 2008. Pathways to social complexity and state formation in the Southern Zambezian region. *African Archaeological Review*, 25(3–4), pp.131–152.
- Knapp, A.B., Pigott, V.C. and Herbert, E.W., 1998. *Social Approaches to an Industrial Past: The Archaeology and Anthropology of Mining*, Psychology Press.
- Knapp, A.B., 1998. Social approaches to the archaeology and anthropology of mining. In E. W. Knapp, A.B., Pigott, V.C. and Herbert, ed. *Social approaches to an industrial past: The archaeology and anthropology of mining*. Psychology Press, pp. 1–23.
- Knox, P.L. & Knox, P.L., 1985. The social production of the built environment Architects , architecture and the post-Modern city. In M. Carmona and S. Tiesdell, ed. *Urban Design Reader*. London: Elsevier, pp. 114–125.
- Kothari, C.R., 2004. *Research methodology: Methods and techniques.*, New Age International.
- Lefebvre, H., 1991. *The Production of Space translated by D Nicholson-Smith.*, Oxford: Blackwell.
- Lewis-Williams, J. D., Blundell, G., Challis, W., and Hampson, J., 2000. Threads of Light : Re-Examining a Motif in Southern African San Rock Art. *The South African Archaeological Bulletin*, 55(172), pp.123–136.
- Li, X. et al., 2011. The impact of early smelting on the environment of Huoshiliang in Hexi Corridor , NW China , as recorded by fossil charcoal and chemical elements. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 305(1–4), pp.329–336. Available at: <http://dx.doi.org/10.1016/j.palaeo.2011.03.015>.
- Ling, J. et al., 2014. Moving metals II : provenancing Scandinavian Bronze Age artefacts by lead isotope and elemental analyses. , 41.
- Lister, L.A., 1987. *The erosion surfaces of Zimbabwe*, Zimbabwe Geological Survey.

- Liu, J. & Jin, S., 2014. The Orebody Character of Pt-Pd Deposits in the Great Dyke, Zimbabwe. *Acta Geologica Sinica - English Edition*, 88(s2), pp.295–296.
- Liu, J., Jin, S. & Wang, Y., 2014. The Occurrence of Useful Components in Platinum-Palladium Deposit in the Great Dyke, Zimbabwe. *Acta Geologica Sinica - English Edition*, 88(s2), pp.1466–1467.
- Lyaya, E.C., 2013. Use of charcoal species for ironworking in. In T. Humphris, J. and Rehren, ed. *The world of iron*. London: Archetype Publications, pp. 444–453.
- M. D. Prendergast, 1974. Research into the ferrous metallurgy Rhodesian Iron Age societies. *Journal of the South African Institute of Mining and Metallurgy*, pp.254–264.
- Maclear, G. et al., 2002. *Compilation of the Hydrological Map and Atlas for the SADC Region Country Report: Zimbabwe*,
- Manyanga, M., 2006. *Resilient landscapes: socio-environmental dynamics in the Shashi-Limpopo Basin, southern Zimbabwe c. AD 800 to the present*, Uppsala: Department of Archaeology and Ancient History, Uppsala University.
- Mapunda, B.B., 1995. *An archaeological view of the history and variation of ironworking in southwestern Tanzania*,
- Mapunda, B.B., 2010. *Contemplating The Fipa Iron Technology*, Kampala: Fountain Publishers.
- Matenga, E., 1993. *Archaeological figurines from Zimbabwe*, Societas Archaeologica Upsaliensis.
- Matenga, E., 2011. *The Soapstone Birds of Great Zimbabwe. Archaeological Heritage, Religion and Politics in Postcolonial Zimbabwe and the Return of Cultural Property*, Upsalla, Sweden: Department of Archaeology and Ancient History.
- Matenga, E., 2011. *The Soapstone Birds of Great Zimbabwe. Archaeological Heritage, Religion and Politics in Postcolonial Zimbabwe and the Return of Cultural Property*. Uppsala.
- Mathoho, E.N. et al., 2016. A technological and anthropological study of iron production in Venda, Limpopo Province, South Africa. *Azania: Archaeological Research in Africa*, 51(2), pp.234–256. Available at: <http://www.tandfonline.com/doi/full/10.1080/0067270X.2016.1177937>.
- Mawere, M., 2013. A Critical Review of Environmental Conservation in Zimbabwe. *Africa Spectrum*, 48(2), pp.85–97.
- Mawere, M., 2012. “Buried And Forgotten But Not Dead”: Reflections on “Ubuntu” in Environmental Conservation in Southeastern Zimbabwe. , 12(10).
- McCosh, F.W.J., 1979. Traditional iron-working in Central Africa with some reference to the ritualistic and scientific aspects of the industry. *Zambezia*, 7(2), pp.155–170. Available at: <http://pdfproc.lib.msu.edu/?file=DMC/AfricanJournals/pdfs/Utafiti/s4NS/aejps004NS008.pdf>.
- Miller, D., 2002. Smelter and smith: Iron Age metal fabrication technology in Southern Africa. *Journal of Archaeological Science*, 29(10), pp.1083–1131.
- Miller, D. & Killick, D., 2004. Slag Identification at Southern African Archaeological Sites. *Journal of African Archaeology*, 2(1), pp.23–47.
- Mitchell, P., 2002. *The archaeology of Southern Africa*, Cambridge: Cambridge University Press.
- Moffett, A.J. & Chirikure, S., 2016. Exotica in Context: Reconfiguring Prestige, Power and Wealth in the Southern African Iron Age. *Journal of World Prehistory*, 29(4), pp.337–382. Available at: <http://link.springer.com/10.1007/s10963-016-9099-7>.

- Moore, A.E. et al., 2009. Landscape evolution in Zimbabwe from the Permian to present, with implications for kimberlite prospecting. *South African Journal of Geology*, 112(1), pp.65–88.
- Morton, G.R., Wingrove, J., 1969. Constitution of bloomery slag: Part 1: Roman. *Journal of the Iron and Steel Institute*, 207, pp.1556–1564.
- Mtetwa, E., 2011. *An Archaeological Perspective of Iron Production in South-central Zimbabwe*. Unpublished Masters Dissertation, University of Dar es Salaam.
- Mtetwa, E., 2011. *An Archaeological Perspective of Iron Production in Southcentral Zimbabwe*. University of Dar es Salaam.
- Mtetwa, E. et al., 2017. When the smith is a woman : innovation , improvisation and ambiguity in the organisation of African iron metallurgy. In S. Manyanga, M and Chirikure, ed. *Archives, Objects, Places and Landscapes: Multidisciplinary approaches to Decolonised Zimbabwean pasts*. Bamenda: Langaa RPCIG, pp. 295–318.
- Mtetwa, R.M.G., 1976. *The Political and Economic History of the Duma People of Southeastern Zimbabwe from the Early Eighteenth Century to 1945*.
- Mudenge, S.I.G., 1988. *A political history of Munhumutapa, c1400-1902*, Harare: Zimbabwe Publishing House.
- Müller, T., 1994. The role a botanical institute can play in the conservation of the terrestrial biodiversity in a developing country. *Biodiversity & Conservation*, 3(2), pp.116–125.
- Ndoro, W., 1994. Natural draught furnaces south of the Zambezi River. *Zimbabwean Prehistory*, (21), pp.29–32.
- Ndoro, W., 2001. *Your monument our shrine: The preservation of Great Zimbabwe*, Department of Archaeology and Ancient History, Uppsala University.
- Peter Mitchell and Gavin Whitelaw, 2005. The Archaeology of Southernmost Africa from c. 2000 BP to the Early 1800s : A Review of Recent Research Author. *The Journal of African History*, 46(2), pp.209–241.
- Phillipson, D.W., 2005. *African Archaeology* 3rd ed., Cambridge: Cambridge University Press.
- Phimister, I.R., 1976., 1976. Pre-colonial gold mining in southern Zambezia: a reassessment. *African Social Research*, 21, p.1–30.
- Phimister, I.R., 1974. Ancient' mining near Great Zimbabwe. *Journal of the Southern African Institute of Mining and Metallurgy*, 74(6), pp.233–237. Available at: https://journals.co.za/content/saimm/74/6/AJA0038223X_354.
- Pikirayi, I. and Schmidt, P.R., 2016. Introduction: community archaeology and heritage in Africa -decolonising practice. In I. Schmidt, P. R. and Pikirayi, ed. *Community Archaeology and Heritage in Africa: Decolonizing Practice*. New York: Routledge, pp. 1–20.
- Pikirayi, I., 2016. Archaeology, local knowledge, and tradition: the quest for relevant approaches to the study of the past in Southern Africa. In I. Schmidt, P. R. and Pikirayi, ed. *Community Archaeology and Heritage in Africa: Decolonizing Practice*. London: Routledge, pp. 112–1135.
- Pikirayi, I. et al., 2016. Great Zimbabwe's water. *Wiley Interdisciplinary Reviews: Water*, 3(2), pp.195–210. Available at: <http://doi.wiley.com/10.1002/wat2.1133>.
- Pikirayi, I., 2013. Stone architecture and the development of power in the Zimbabwe tradition AD 1270 – 1830. *Azania: Archaeological Research in Africa*, 48(2), pp.282–300. Available at: <http://dx.doi.org/10.1080/0067270X.2013.789225>.
- Pikirayi, I., 2006. *The demise of Great Zimbabwe, AD 1420-1550: an environmental re-appraisal*, na.

- Pikirayi, I., 2001a. The physical environment and landscapes of the Zimbabwe culture states. In *People, Contacts and the Environment in the African Past*. Dar es Salaam: Dar es Salaam University Press, p. 129–150.
- Pikirayi, I., 2001b. *The Zimbabwe Culture: Origins and Decline of Southern Zambezi States.*, Walnut Creek: Altamira Press.
- Pikirayi, I., 2017. Trade , Globalisation and the Archaic State in Southern Africa. *Journal of Southern African Studies*, 7070(July), pp.1–15. Available at: <http://doi.org/10.1080/03057070.2017.1344923>.
- Pleiner, R., 2000. *Iron in Archaeology: the European Bloomery Smelters.*, Prague: Archaeologický Ústav Av.
- Pollard, M., Chirikure, S., Uchida, J., Zhnag, C., and Iizuka, Y, ., 2016. Social Archaeometallurgy: The Role of Metals within and between Societies. In WAC-8 Kyoto Local Organizing Committee, ed. *The Eighth World Archaeological Congress, Kyoto, Japan, August 28th - September 2nd, 2016*. Kyoto: Sansei Printing Co., Ltd., pp. 289–290.
- Prendergast, M.D., 1975. A new furnace type from the Darwendale Dam basin. *Rhodesian Prehistory*, 7(14), pp.16–20.
- Prendergast, M.D., 1979. Iron Age settlement and economy in part of the southern Zambezi Highveld. *South African Archaeological Bulletin*, 34(130), pp.111–119.
- Prendergast, M.D., 1979. Iron Age Settlement and Economy in Part of the Southern Zambezi Highveld. *The South African Archaeological Bulletin*, 34(130), pp.111–119.
- Prendergast, M.D., 1974. Research into the ferrous metallurgy Rhodesian Iron Age societies. *Journal of the South African Institute of Mining and Metallurgy*, pp.254–264.
- Pwiti, G., 1996. *Continuity and change: an archaeological study of farming communities in northern Zimbabwe*. Uppsala University.
- Pwiti, G., 1991. Trade and Economies in Southern Africa: The Archaeological Evidence. *Zambezia*, XVIII(II), pp.119–129.
- Randall-MacIver, D., 1906. *Mediaeval Rhodesia*, New York: The MacMillan Company.
- Rehder, J.E., 2000. *Mastery and Uses of Fire in Antiquity*, MQUP.
- Rehren, T., 2000. Archaeometallurgy — an island? *Antiquity*, 74(286), pp.964–967.
- Roberts, B .W. and Thornton, C.P. ed., 2014. *Archaeometallurgy in Global Perspective: Methods and Processes*, New York: Springer.
- Schmidt, P., 1998. Reading gender in the ancient iron technology of Africa. *Gender in African prehistory*, pp.139–162.
- Schmidt, P.R., 1994. Historical Ecology and Landscape Transformation in Eastern Equatorial Africa. In *Historical Ecology: Cultural Knowledge and Changing Landscapes*. School of American Research Press.
- Schmidt, P.R., 2009. Tropes, Materiality, and Ritual Embodiment of African Iron Smelting Furnaces as Human Figures. *Journal of Archaeological Method and Theory*, 16, pp.262–282.
- Schmidt, P.R. & Mapunda, B.B., 1997. Ideology and the Archaeological Record in Africa: Interpreting Symbolism in Iron Smelting Technology. *Journal of Anthropological Archaeology*, 16(1), pp.73–102.
- Scholtz, A., 1986. *Palynological and Plaeontological Studies in the Southern Cape*. Stellenbosch University.
- Serneels, V. & Perret, S., 2003. Quantification of smithing activities based on the investigation of slag and other material remains. , 1, pp.469–478.

- Sinclair, P.J., 1984. *Rescue Excavation of a Furnace at Gokomere Mission, Zimbabwe*, National Museums and Monuments of Zimbabwe.
- Sinclair, P.J.J., 1987. *Space, time and social formation: a territorial approach to the archaeology and anthropology of Zimbabwe and Mozambique c 0-1700 AD*, Uppsala: Societas archaeologica Upsaliensis: Institute of Archaeology [Institutionen för arkeologi], Univ. [distributör].
- Sinclair, P.J.J., Ekblom, A. & Wood, M., 2012. Trade and Society on the South-East African Coast in the Later First Millennium AD: The Case of Chibuene. *Antiquity*, 86(May), pp.723–737.
- Smedley, J.W., Jackson, C.M. and Welch, C.M., 2001. Unravelling glass compositions: glassmaking raw materials at Little Birches, Staffordshire. In *Annales du 15e Congres de l'Association Internationale pour l'Histoire du Verre e New York-Corning*. New York: Corning, pp. 203–7.
- Stern, W.B., Gerber, Y. & Natrun, W., 2004. Potassium -Calcium Glass: New Data and Experiments. , 1(July 2003), pp.137–156.
- Summers, R., 1969. *Ancient mining in Rhodesia and adjacent areas*, Salisbury.
- Summers, R., Robinson, K.R. & Whitty, A., 1961. *Zimbabwe excavations 1958*, National Museums of Southern Rhodesia.
- Summers, R.F., 1958. *Inyanga: prehistoric settlements in Southern Rhodesia*, Published for the Inyanga Research Fund at the University Press.
- Swan, L., 2007. Early iron manufacturing industries in semi-arid, south-eastern Zimbabwe. *Journal of African Archaeology*, 5(2), pp.315–338.
- Swan, L.M., 1994. *Early gold mining on the Zimbabwean plateau: changing patterns of gold production in the first and second millennia AD*, Uppsala: Societas archaeologica Upsaliensis: Dept. of Archaeology [Institutionen för arkeologi], Univ. [distributör].
- Swan, L.M., 2007. Early iron manufacturing industries in semi-arid, south-eastern Zimbabwe. *Journal of African Archaeology*, 5(2), pp.315–338.
- Swan, L.M., 2008a. *Minerals and managers: production contexts as evidence for social organization in Zimbabwean prehistory*, Uppsala: [Institutionen för arkeologi och antikhistoria], Uppsala Universitet.
- Swan, L.M., 2008b. *To Ian, Jessica and Sean*,
- Tabor, G.R., Molinari, D. & Juleff, G., 2005. Computational simulation of air flows through a Sri Lankan wind-driven furnace. *Journal of Archaeological Science*, 32(5), pp.753–766.
- Terry Childs, S., 1991. Style, technology, and iron smelting furnaces in Bantu-speaking Africa. *Journal of Anthropological Archaeology*, 10(4), pp.332–359.
- Tite, M.S., 2008. Cermaic Production , Provenance and Use — A Review. , 2(December 2007), pp.216–231.
- Trigger, B.G., 2003. *Understanding early civilizations: a comparative study*, New York: Cambridge University Press.
- Tusenius, M.L., 1986. *The study of charcoal from some southern African archaeological contexts*. 1986. Stellenbosch University.
- Veldhuijzen, H. A. and Rehren, T., 2014. Slags and the city : early iron production at Tell Hammeh, Jordan, and Tel Beth-Shemesh, Israel. In P. T. C. S. La Niece, D.R. Hook, ed. *Metals and Mines — Studies in Archaeometallurgy*. Archetype, British Museum, pp. 189–201.
- Venter, F., & Venter, J.A., 1996. *Making the most of indigenous trees*, Briza publications.
- Vogelsang, R., & Eichhorn, B., 2011. *Under the mopane tree: Holocene settlement in northern Namibia (Vol. 24)*., Heinrich Barth Institut eV.

- Walker, N.J., 1995. *Late Pleistocene and Holocene hunter-gatherers of the Matopos: an archaeological study of change and continuity in Zimbabwe*. Uppsala: Societas archaeologica Upsaliensis.
- Warnier, J.-P., 2009. Technology as efficacious actions on objects and subjects. *Journal of Material Culture*, 14(4), pp.459–470.
- Wild, H., and Barbosa, L.A.G., 1967. Vegetation map of the Flora Zambesiaca area. In A. M. O. Wild, H., and Fernandes, ed. *Flora Zambesiaca*. Salisbury: Collins.
- Willoughby, J.C., 1893. *A Narrative of Further Excavations at Zimbabwe (Mashonaland)*. G. Philip & son.
- Wilson, J.F., 1973. The Rhodesian Archaean craton-an essay in cratonic evolution. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, 273(1235), pp.389–411.
- Wilson, J.F., Nesbitt, R.W. & Fanning, C.M., 1995. Zircon geochronology of Archaean felsic sequences in the Zimbabwe craton: a revision of greenstone stratigraphy and a model for crustal growth. *Geological Society, London, Special Publications*, 95(1), pp.109–126.
- Witmore, C., 2014. Archaeology and the New Materialisms. *Journal of Contemporary Archaeology*, 2, pp.1–44.