Dissertation By

Edwinus Chrisantus Lyaya

University of Dar es Salaam

THE PHYSICAL PROPERTIES OF METALLIFEROUS SLAG: A COMPARISON BETWEEN SMELTING AND SMITHING PROCESSES

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M.A (Archaeology) Dissertation
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Edwinus Chrisantus Lyaya

A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Arts (Archaeology) of the University of Dar es Salaam

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CERTIFICATION

The undersigned certifies that he has read and hereby recommends for examination a dissertation entitled ***The Physical Properties of Metalliferous Slag: A Comparison between Smelting and Smithing Processes***, in fulfilment of the requirements for the degree of Master of Arts (Archaeology) of the University of Dar es Salaam.

____

Bertram B.B. Mapunda (PhD)

(Supervisor)

Date:__________________________________

DECLARATION

AND

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I, **Edwinus Chrisantus Lyaya**, declare that this dissertation is my own original work and that it has not been submitted and will not be presented to any other university for a similar or any other degree award.

Signature ______________________________________

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Lastly, I believe that I may have omitted one's name. Although it may be so, I beg you to take that as a mere oversight. This is because I believe that "If you have faith no reason or proof that is necessary, but if you have no faith no reason or proof that is possible." I hope that you will continue helping me in my dreams for education. I thank God for care and protection.

DEDICATION

I dedicate this dissertation to Marta Ribas in Spain, Nieves Mohedano in Canada, PRH Educators and to my parents Chrisantus Oscar Lyaya (father) and Agnes Pascal Magenda (mother). Their care, financial help and moral support have enabled my education dreams become feasibly true. I give them the following verse from the Holy Bible, “Na Mungu wangu atawajazeni kila mnachohitaji kwa kadri ya utajiri wake, katika utukufu, ndani ya Kristu Yesu (Filp. 4:19)”.

ABSTRACT

African iron working technology involved smelting, refining, and smithing technological and functional processes or stages. These produced three respective metalliferous slag types namely smelting slag, refining slag and smithing slag. Unfortunately, not all writers are clear with the distinction of the three types. Some recognize smelting slag alone, others recognize smelting and smithing slag, and yet others confuse between refinery and smithing slag.

This work examines the physical properties of metalliferous slag with emphasis on smelting and smithing. It has left out refinery slag because not all smelted iron was refined, but all smelted iron was ultimately forged. The examination is based on samples from incontrovertible smelting and smithing sites. Physical attributes for each type of slag have been identified with a view to establish distinguishing criteria between smelting and smithing slag.

The research has found out that smelting and smithing slag are quite different in terms of general size, mass or weight, density, morphology, thermal condition, magnetism, fragmentation, weathering, and surface conditions. This work shows that the two are closely related in such attributes as luster, color(s), porosity, inclusion, impressions and source materials. Through the study of the physical attributes, it is therefore possible to distinguish smelting from smithing slag, and so smelting from smithing sites. However, the role of matrix and provenience is also important in ascertaining the two categories.

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CHAPTER ONE

INTRODUCTION

1.1 Preamble

Archaeometallurgy is an archaeological technology of processing metals. This technology involved smelting, refining and smithing processes (Blomgren and Tholander 1986). Each of these processes produced respective wastes called slag (Friede *et al.* 1982). Slag, which in true sense is once molten (or may not have reached melting point) silicate or silicate mixture including oxides, phosphates, borates, sulphides, antimonides, carbides, and pure metals (Rostoker and Bronson 1990), is commonly understood as waste, discarded or left behind metallurgical processes (Bachmann 1982). The archaeometallurgical study of slag has revealed clarity problems because scholars are not clear with the distinction between types of metalliferous slag. This tendency of confusing slag types may have negative ends as it could lead to wrong assumptions or conclusions. This dissertation is a solution to this problem because it examines the properties of smelting and smithing slag and establishes the distinguishing criteria for the respective slag types.

1.2 Statement of the Problem

Smelting, refining and smithing are the principal metallurgical processes which yield three respective types of metalliferous slag, namely smelting, refinery, and smithing slag (Greig 1937, Rosemond 1943, Wise 1958, Brock 1963, Wembah-Rashid 1969, Pole

1985, Davison and Mosley 1988, David *et al.* 1989, Collett 1993). While the study of slag has been an important sub-field in archaeometallurgy (Rostoker and Bronson 1990), not all archaeometallurgists are clear with the distinction of the three types. For example, there are those who recognize smelting and smithing slag types alone (Bachmann 1982, Friede *et al.* 1982:38, van Noten 1985: 118, Filipowiak 1985:36, Larick 1986), while others put emphasis on smelting slag alone (van Noten and Raymaekers 1988:107), and yet others confuse between refinery and smithing slag (Bachmann 1982, Friede *et al.* 1982, Filipowiak 1985, Allen 1986, Rostoker and Bronson 1990). All these groups of scholars make serious mistakes as the technological and functional differences of the processes (or slag) are not given their due weight. To settle this confusion, this study uses physical attributes that can be easily identified by lay field archaeologists to make the distinction. Working within the time allowed, the study has concentrated on smelting and smithing iron slag, leaving out refinery iron slag since not all smelted iron was refined, but all smelted iron was ultimately forged (Brock 1963, van Noten 1985, Davison and Mosley 1988).

1.3 Research Objectives

The overall objective of this study is to establish criteria for distinguishing smelting from smithing iron slag. This is fulfilled under the following specific objectives: (1) to examine physical properties of smelting and smithing slag and (2) to determine distinguishing criteria of the two types of slag.

1.4 Hypothesis and Testing Implications

This study had been guided by the hypothesis that smelting and smithing metalliferous slag are different. From this general assumption, it was predicted that the two vary in physical attributes or properties that are determinable and can, therefore, be identified and be used to distinguish smelting from smithing slag, and hence smelting from smithing sites.

1.5 Significance of the Study

The study removes the confusion between the two slag types. In addition, it stands as a future field guide for the identification of the two metalliferous sites. It also adds to the existing body of resources about ironworking technology and metallurgy in Tanzania.

1.6 Theoretical Framework

The study employs a functional approach, that is, it examines the different metalliferous processes and discerns types of slag resulting from them on a functional basis. In other words, the formation of metalliferous slag depended on the functions of metallurgical processes. For example, smelting slag was formed from smelting process whose function was to reduce ore to a bloom; refinery slag was formed in the process of purifying bloom to get a pure metal; whereas smithing slag was formed during forging process where tools were produced. This shows that every process was technologically and functionally different.

1.7 Dissertation Content

This dissertation is organized into eight chapters: (1) introduction, (2) essence of slag, (3) literature review, (4) research methods, (5), presentation and analysis of smelting slag, (6) presentation and analysis of smithing slag, (7) Comparative analysis: smelting vs. smithing slag and (8) conclusions and suggestions.

Chapter two discusses the essence of slag in terms of three metallurgical processes or stages responsible for the production of slag. The literature review focuses on what other scholars have written on the research topic. Chapter four explores the research methods adopted in the production of this dissertation, while chapter five presents analyzed smelting slag and chapter six presents analyzed smithing slag. Chapter seven deals with a comparative analysis of smelting and smithing slag with a view to establish their distinguishing criteria. The last chapter provides conclusions on the research problem and suggestions.

1.8 Summary

This chapter has introduced this dissertation in terms of research pillars and its contents. Itself as a chapter has introduced the main concern of each chapter and hence the entire work.

CHAPTER TWO

ESSENCE OF SLAG

2.1 Preamble

This chapter discusses the essence of metalliferous slag. It explores the processes of African iron working technology, which involve smelting, refining and forging processes with the focus on how each of these processes produces slag, hence the three types of slag namely, smelting, refining and smithing.

2.2 African Basic Metalliferous Processes

Generally speaking, iron working technology in Africa involved three respective metallurgical stages or processes namely smelting, refining, and smithing (Brock 1963, Sutton 1985, Blomgren and Tholander 1986:160, Collett 1993). Smelting process involved the reduction of an ore to bloom (Bachmann 1982, Childs and Schmidt 1985, Allen 1986, Killick 1987) or to cast iron (David *et al*. 1989: 184). The former was a product of bloomery process while the latter was a product of blast furnace, which respectively produced low carbon iron (wrought iron or steel) and high carbon content, liquid iron (cast iron) (Rostoker and Bronson 1990:90).

In simple chemistry, the process involved the separation of iron atoms from the oxygen atoms to which they are bonded in the oxides (FeO) (Avery *et al*. 1988, Mapunda 2002b). This is achieved by causing the oxygen in the ore to combine with carbon monoxide (CO) gas produced by the reaction of charcoal with the air inside the furnace (Mapunda 1995, 2002a). Carbon dioxide (CO_2) may develop later from CO and escapes into the air. For example a reaction of magnetite ore can be summarized as follows: $Fe_3O_4 + 4CO \rightarrow 3Fe + 4CO_2$ (David *et al*. 1989).

Many researchers have found that smelting activities took place away from settlements (Greig 1937, Larick 1986, Davison and Mosley 1988, Childs 1991, Mapunda 1995, 2002a). This was for several reasons. First, it was because of associated taboos such as avoiding the presence of women (Davison and Mosley 1988:61) and rituals such as seclusion. Second, the smelters wanted to be close to raw materials such as ores and wood (Greig 1937, Childs 1991). Third, fire in the residential areas could burn the grass-thatched houses. Fourth, multiple other factors, ranging from ideological, political to economic ones: For example, the early Njanja group of the Mashona in Zimbabwe built their furnaces on land they conquered, but paid a neighboring chief to mine the excellent iron ore he controlled (Childs 1991:343). However, we need to note that Haaland and Msuya (2000) have found in Dakawa, near Morogoro, eastern Tanzania, that smelting activities took place within settlements. But this is rather exceptional as far as African iron working is concerned.

Smelting process started with the collection of sufficient amount of raw materials such as ore, fuel (charcoal and wood), and medicinal herbs and animal parts (Rosemond 1943, van Noten and Raymaekers 1988, Childs 2000, Mapunda 2002b). It also involved the construction of a smelting furnace, tuyeres, and bellows. The use of medicines, known to smelters (and smiths) alone (Rosemond 1943, Phillipson 1968), served the function of ensuring good product (Phillipson 1968, Wembah-Rashid 1969, Killick 1987, Davison and Mosley 1988). These when mixed together in the furnace entered into complex physical and chemical reactions during smelting, resulting in metallic iron and slag (Mapunda 2002a).

Chemically, the reduction begins at a temperature of about 800^{o}C and the separation of slag begins at about 1150^{o}C (van Noten and Raymaekers 1988, Childs 1991). How is slag formed? The non-metallic gangue liquefies and tends to drain away as slag, while the particles of metallic iron tend to collect as droplets and lumps in a slag matrix (David *et al.* 1989, Avery *et al*. 1988:263). It is important to note that smelters knew exactly when iron bloom had collected as they could tell from the noise made by bubbling slag, the level of the furnace contents which appeared to be at the tuyeres, and the color of the flame (Todd and Charles 1978). The outcome of the reduction was a spongy-looking bloom that consisted of iron, slag, and other impurities. In many cases the bloom was good enough for direct forging into tools. This was the case in Buhaya (Schmidt and Avery 1978) and eastern Lake Nyasa region (Mapunda 2002a). When the bloom was not pure enough, it was refined.

Refining process was essential to remove impurities, such as slag, charcoal, sand, and other material from the crude bloom (Rosemond 1943:84; van Noten and Raymaekers

1988). This was necessary especially with laterite ore that apparently was too low to form any free iron (Killick 1987:28). In fact, it was practically not possible in the traditional process to get 100 percent pure iron from smelting process.

Refining was done near or in a village (Greig 1937:79). It employed small, forced –draft furnaces (also called secondary furnaces) (Brock 1963, Todd and Charles 1978, Plundergast 1983, Pole 1985) or miniature blast furnaces (Greig 1937). Sometimes iron workers used open crucibles, as in the case of the Mafa – ironworking technology (David *et al*. 1989). As was for smelting, refining process involved several stages: 1) Erecting a furnace, 2) boring draught holes into the walls and piece of draught pipe fitted into them, and 3) loading the furnace which started with placing charcoal at the bottom. Onto this were put some hot embers level with the draught holes, on top of these was another layer of charcoal, and above this layer were placed pieces of crude iron bloom surrounded by charcoal. This pattern was repeated until the furnace was full. The furnace was then lit and bellowing continued along with recharge of charcoal. As the temperature increased, slag formed and was allowed to drain out leaving behind iron at the bottom of the furnace. When slag stopped running the iron was ready. The draught pipes were knocked out, the embers pulled from the bottom of the furnace, and the red-hot lump of iron was lifted out with tongs and thrown to the ground outside. The iron was now pure to be forged (Wise 1958:110-111).

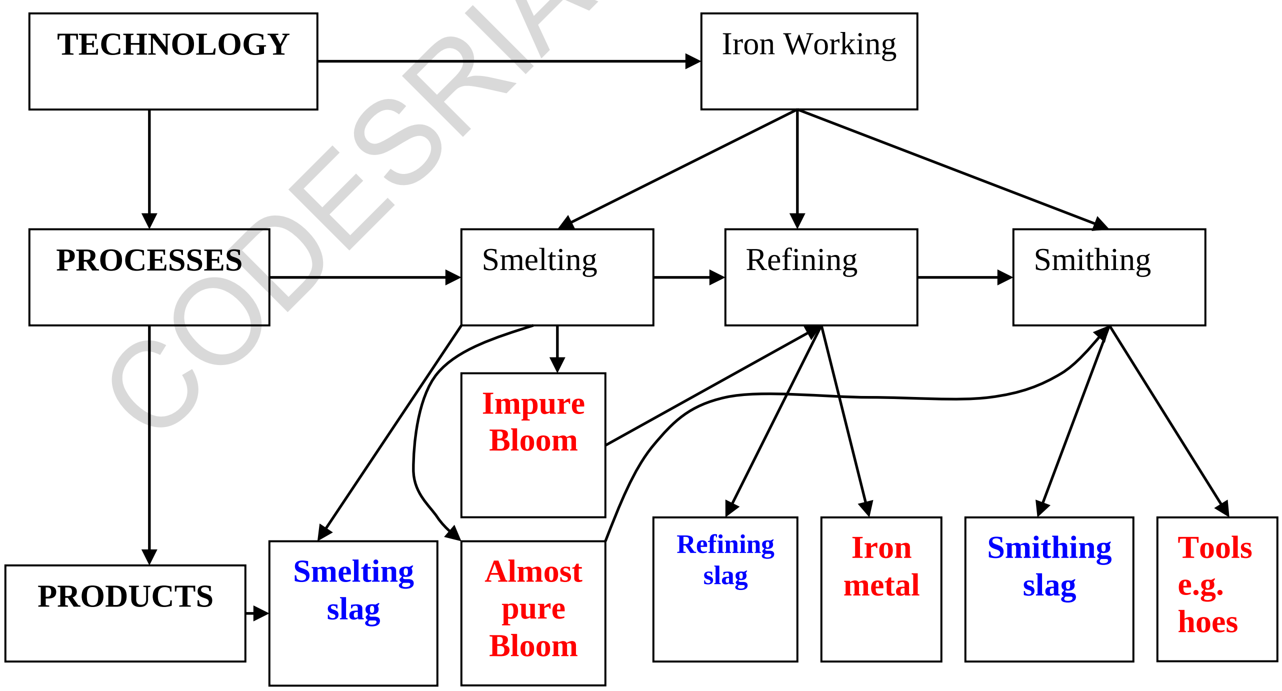
Smithing process involved forging of the iron from refining process into implements. Forging was the most exciting part of the whole work as it led to production of utilitarian tools such as hoes, knives, spears, and bill-hooks for cultivation, and weapons for wars (Greig 1937), and the production of objects (or ornaments) for symbolic functions, whereby attention was paid to morphological and surface details that were critical to symbolic use (Childs n.d., van Noten and Raymaekers 1988). This made the smiths (or *silungu* as in Fipa, Greig 1937), respected leaders in scared rituals (Larick 1986:166, Mapunda 2004). Also, chiefs recognized them and gave the craftsman their special clothes (Greig 1937). People were not allowed to invade smiths in any case of disputes (Childs 2000) and were feared as they possessed magical powers (Maquet 1972: 83, Haaland 2005:197). So, not everyone could do smithing (Pole 1985:155) only few families in a village could.

The process took place in residential areas (Herbert 1993), and used smithing hearths which could be placed in an open air, under a tree or inside a simple hut (Wise 1958). In any case, a forge would constitute a hearth, an anvil (big stone), and a hammer (stone or iron). The raw iron was put into the hearth and surrounded it with charcoal, which was then blown up into a white heat with a single or up to three sets of bellows. When it was hot enough, the smith took it from the fire and put it on the anvil and hammered it. Beaters used large flat-bottomed stones or iron hammers, which they lifted above their heads and brought down with all strength to smite the iron, setting off sparks flying in all direction (Wise 1958). In real sense, it is these sparks that formed droplet type of smithing slag. Also, while beating the metal scale-like slag formed. When the iron got the needed shape, they used lighter stones or hammers for finishing.

2.3 Summary

This chapter has discussed the three metallurgical processes namely smelting, refining and smithing. It has shown that each stage in terms of technology and function was significant in the production of respective slag and other materials. Each type, therefore, will have properties that can distinguish it from the other, and this study aims at identifying and presenting them. What has been presented in this chapter can be diagrammatically illustrated as follows (Figure 2.1):

Figure 2.1: Process of Slag Production



CHAPTER THREE

LITERATURE REVIEW

3.1 Preamble

This chapter specifically focuses on previous research works related to studies on classification of slag. It is organized in such a way that it moves from general works to specific literatures. It begins by providing the unique features of African iron technology. It ends by reviewing the history of archaeological researches in the research areas for this study. The review helps to establish an intellectual puzzle and gap that formed the research problem of this work.

3.2 Features of Ancient African Iron Working Technology

African iron working technology is unique in many ways. First, it is greatly variable. For example, furnaces differ not only in form but also in techniques used to construct them. Such differences could be discerned even among smelters located in close geographical and temporal proximity (Avery *et al.* 1988). Second, iron smelting involved both bloomery and blast processes (David *et al.* 1989). Third, it was a sophisticated technology. For example, preheating, a critical component of African iron smelting, involved the use of long tuyeres 40-60cm the long part of which was inserted inside the smelting furnace (Avery and Schmidt 1979, Schmidt and Avery 1983, Avery *et al.* 1988:281, Haaland and Msuya 2000). This technique has been clearly documented in Buhaya, western Lake Victoria region where it dates to between 2000 – 1500 years ago (Childs and Schmidt 1985). Preheating temperatures between 500-600^{0}C for air inside the clay tuyeres that were located inside the furnace (Schmidt and Avery 1978). Lastly, traditional iron bloomeries in Africa have survived or continued until the beginning of the 20th century (van Noten and Raymaekers 1988:104). All these features make African iron technology an interesting subject to study.

3.3 Studies on Metalliferous Slag: Lack of Clarity

Iron technology in Africa involved three stages which resulted in three respective types of slag (see Chapter Two). While the processes included smelting, refining and forging, the respective slag included smelting slag, refining slag and forging slag. Studies on slag form an important part in archaeometallurgy (Rostoker and Bronson 1990). Despite that fact, studies on classification of slag are extremely rare coupled with clarity problems. This means, not all archaeometallurgists are clear with the distinction of the three types of metalliferous slag. In other words, a good number of archaeometallurgical studies have not appreciated the three separate metallurgical processes when analyzing slag. For example one group confines iron slag to smelting process. Such scholars include van Noten and Raymaekers (1988:107) who define slag as "the waste from smelting process". This group ignores refinery and smithing slag. The second group identifies only smelting and smithing iron slag ignoring refinery slag. Examples include Bachmann (1982), Friede *et al.* (1982), van Noten (1985: 118), Filipowiak (1985:36), and Larick (1986). Friede *et al.* (1982:38) for instance writes, "besides the 'true' smelting slags, another type of slag has been described. This type, called smithing slag, may be produced in small quantities when, under essentially oxidizing conditions, the bloom is hammered out on a smithing hearth". The last group confuses between refinery and smithing iron slag. Good examples include Bachmann (1982), Friede *et al.* (1982), Filipowiak (1985), Allen (1986), and Rostoker and Bronson (1990). Allen (1986:97) for instance writes, "we are here mainly concerned with the character of some of the slag- known as smithing slag – formed during the second stage". Here Allen confuses readers since second stage in the metallurgical processes as explained in chapter two is refining, but he calls it "smithing"! It seems like refinery and smithing, which are technologically and functionally different, are lumped together. The interpretations of slag given by these scholars lack clarity. This is a weakness that has been addressed by this work through a rigorous examination of the physical attributes of each type in order to appreciate the processes that functionally and technologically formed it.

3.4 The History of Archaeological Researches in the Study Areas

The study area comprised of two regions, Northern Pemba and Iringa. Previous archaeological researches in Northern Pemba focused on two main aspects: the history of stone buildings and the people, who lived in urban centers (Horton and Clark 1985) and the history and civilizations of Swahili speaking people (Fleisher and LaViolette 1999, LaViolette 2000, LaViolette *et al.* 2002, Fleisher 2003, LaViolette *et al.* 2003, 2004, Walshaw 2005). The second phase has retrieved numerous iron working materials. The analyses by Bertram Mapunda suggest that iron was smelted in Northern Pemba (2000 cited in LaViolette *et al.* 2002, Mapunda 2002b, LaViolette *et al.* 2003). The factors for the rise and the fall of iron working in Northern Pemba have been explained to be influenced by both internal and external factors (Lyaya 2005). Lastly, Mapunda's (2006) Metallurgical report shows, among other things, that there was smithing in Northern Pemba as per findings from Tumbe. But so far no one has done any study on the properties of metalliferous slag in Pemba.

The history of archaeological researches in Iringa has focused on four main aspects: (1) the technology of Stone Age deposits of Isimila (Howel 1961, Cole and Kleindienst 1974, Clark 1988), culture and environment (Hansen and Keller 1971), dating of deposits (Howel 1972), and the cultural sequences of the later prehistory of Ismila (Willoughby 2007, Kimaro forthcoming), (2) the history of the Bena (Nyagava 1988), (3) Cultural Heritage Impact Assessment (CHIA), which is part of Environmental Impact Assessment (EIA) (Masao 1995, Msemwa 1996a, 1996b) and (4) symbolism in iron smelting (Halifan 2005). The production of iron was a common practice among the people of Iringa (Nyagava 1988).They used superstructure furnaces, which were hidden in steep valleys, away from noise, women and strangers who were believed to harm the work (Halifan 2005). While archaeological researches reveal a basic uniformity in the principles and methods of iron working throughout Tanzania, Nyagava (1988) has found out that there has been at the same time considerable variations in details of furnaces, forging instruments, and the wares produced. Factors for these variations, he notes, reflect either local traditions or are natural depending on the availability of ores (Nyagava 1988:152). Nyagava (1988) adds that iron making was a prominent craft, which revolutionalized agriculture in terms of iron tools for more productivity. Iron technology declined there in the early twentieth century due to, among other factors, the importation of manufactured iron tools (Mapunda 2002a). Masao's (1995) and Msemwa's (1996a, 1966b) archaeological reports have focused on hydropower developmental projects at Lower Kihansi and Upper Kihansi respectively with a view to assess the cultural potentials that were likely to be destroyed by dam construction. Halifan's (2005) study has focused on iron smelting symbolism in Njombe, Iringa Rural and Mufindi districts. Randi Barndon (2004) argues that among Pangwa iron workers the use of magic and medicines, as well as an overall thermodynamic conception of the body, was transferred from personal and collective lived experience by metaphorical imagination to the iron smelting furnaces. In all these studies, the properties of metalliferous slag have not been explained from Iringa, hence the justification of this study.

3.5 Summary

From the review, we see that archaeometallurgical studies have not given due weight and consideration to the technological and functional differences of the processes and the resulting slag. It is this gap that gave impetus to this work.

CHAPTER FOUR

RESEARCH METHODS

4.1 Preamble

This chapter explores various strategies of inquiry and research methods used to gather data and produce this dissertation. It begins by justifying the research approach or design and by showing the rationale of the study areas, sample and sampling procedures. The remaining part concentrates on pre-field research methods, field research methods and laboratory techniques.

4.2 Research Approach

This work seeks to understand the physical attributes or properties of metalliferous slag and hence use them as the basis for distinguishing smelting and smithing slag. Physical attributes are quantifiable data. This called for the use of quantitative research approach in designing, collecting, and analyzing data. However, qualitative data was also collected at Ngongwa smelting site in Iringa and at the modern forge of Mpembani, Northern Pemba. This allowed a combined approach for a more comprehensive explanation.

4.3 Study Areas

This study was conducted at metalliferous smelting and smithing sites. The study investigated two smelting sites namely Ngongwa, five kilometers from Kalenga (Mkwawa Museum) in Rural Iringa district and Msete, seven kilometers to Hagafilo and 12 kilometers from Njombe Bus Stand in Njombe District, Iringa Region, Tanzania (Figure 4.1). On the other hand, metalliferous smithing slag was collected from Tumbe in Micheweni District, Northern Pemba Region (Figure 4.2) as reported by Mapunda (2006) and Nundu sites in Njombe District, Iringa Region. Mpembani is a modern smithing site. It has been included in this study for comparative purposes between ancient smithing slag and modern smithing slag.

In terms of mineralogical geology, the research areas are different. While there are no iron bearing rocks in Northern Pemba (Lyaya 2005), Pinna *et al.* (2004) demonstrate abundant magnetite iron ores in Iringa. This fact has been used respectively to differentiate imported iron and local iron between the areas in terms of slag produced, and hence sites selection described in section 4.4.

Figure 4.1: Location of Sites from Iringa Region

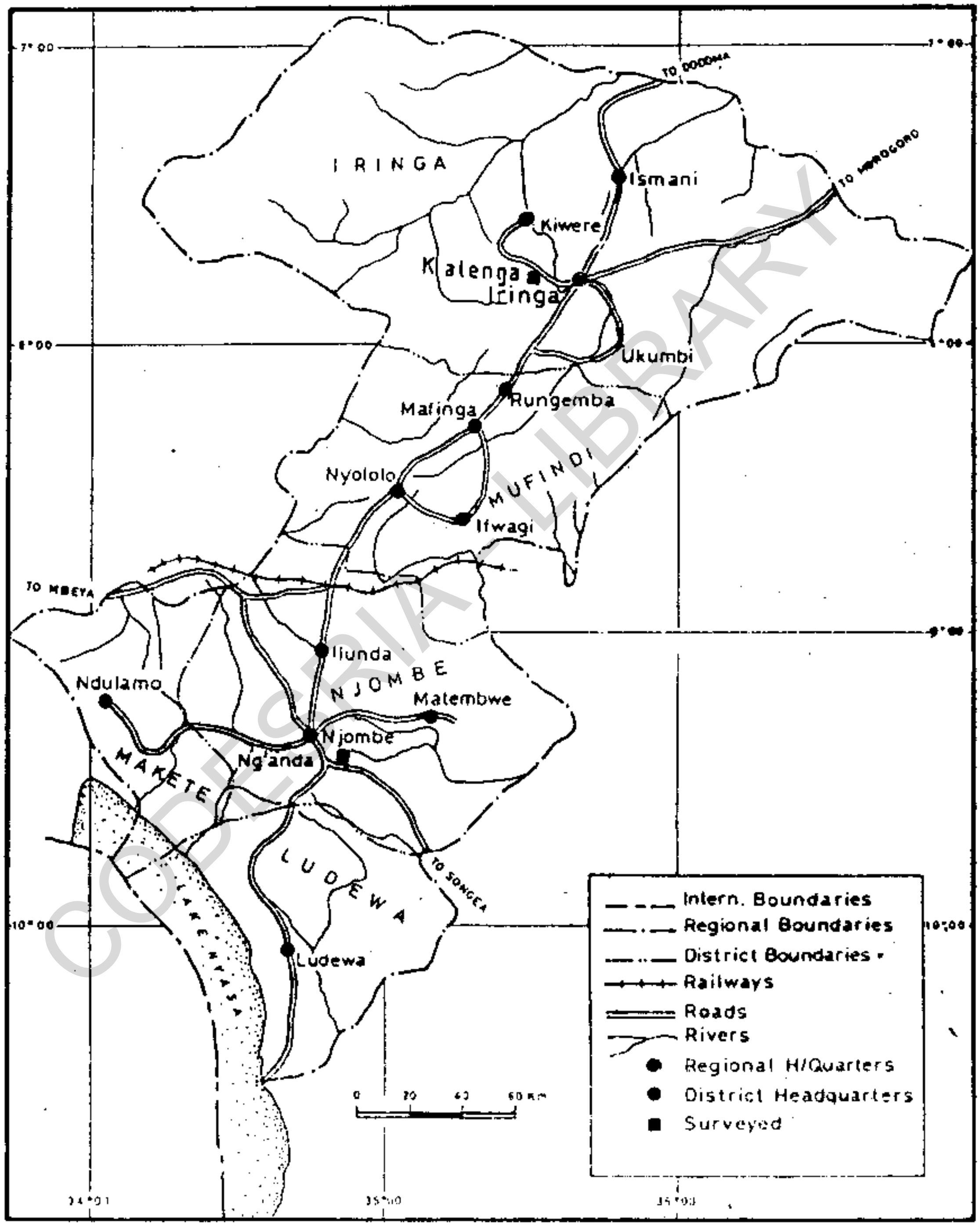
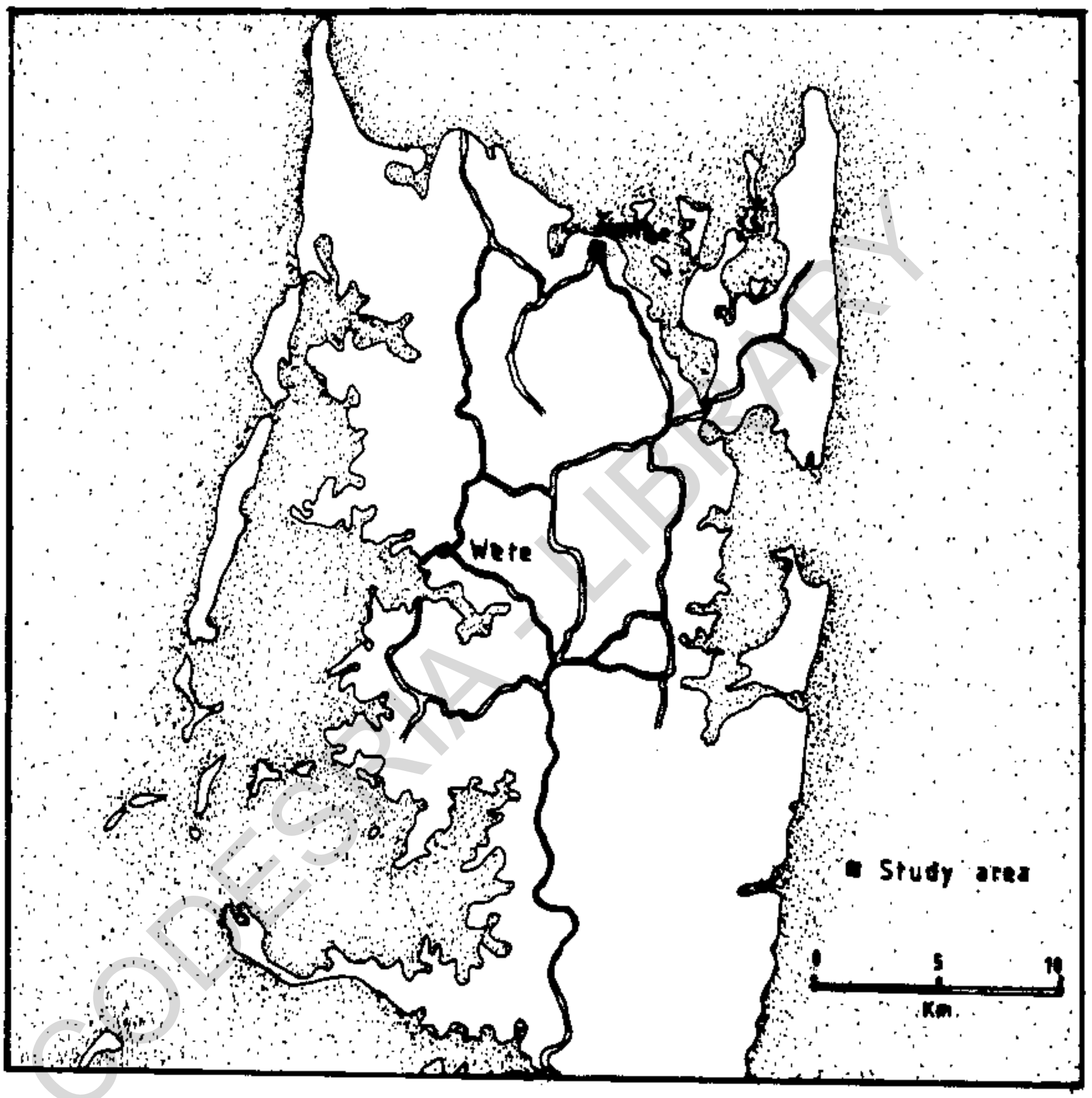


Figure 4.2: Map of Northern Pemba Sites



4.4 Site Selection

The sample constituted two smelting sites, two ancient smithing sites, and one modern smithing site made of two forges (Plates 4.1 and 4.2). These sites were selected using non-systematic sampling procedures (Renfrew and Bahn 1996). The main concern was to make sure quality information for the research problem is obtained. At specific level there are several other reasons for the selection of both smelting and smithing sites. Despite the fact that there are many smelting sites in Tanzania, the study focused on the given sites because the study called for sites that are incontrovertibly smelting or incontrovertibly smithing so as to be certain that the slag studied are certainly representative of the process needed. Ngongwa smelting site is evidently smelting because it has bowl furnaces (Plate 4.3), slagy tuyere (Plate 4.4). Msete smelting site bears also these features but with superstructural, truncated cone furnaces (Plate 4.5 and 4.6). To be certain that all types of smelting slag are studied, it was necessary to have slag from both inside (Plate 4.7) and outside the furnace.

Plate 4.1: Mpembani Forge 1

Plate 4.2: Mpembani Forge 2

Plate 4.3: Ngongwa Bowl Furnaces

Plate 4.4: Tuyere Slag

Plate 4.5: Msete Tall Furnace 1

Plate 4.6: Msete Tall Furnace 2

Plate 4.7: Inside the Furnace 1 Smelting Slag

On smithing sites, Nundu and Tumbe were sampled because they are incontrovertibly smithing. Nundu site in Njombe, for example consists of a smithing hearth (Plate 4.8), an anvil (Plate 4.9), hammers (Plate 4.10) and slag. Tumbe site in Northern Pemba, is evidently smithing because it is still in use, plus it has a smithing hearth and droplet and scale slag in large quantities. Both sites provided main types of ancient metalliferous smithing slag.

Plate 4.8: Nundu Smithing Hearth

Plate 4.9: Nundu Smithing Anvils

Plate 4.10: Nundu Smithing Hammers

In addition, Mpembani modern smithing slag at the two forges was studied to determine their physical attributes with the view to compare with physical properties of smithing slag from ancient sites. These sites have satisfactorily answered questions intended for by the study.

4.5 Pre- Field Preparations

This category included reviewing literatures and writing a research proposal based on the established academic gap from the literature consulted, presenting and defending the proposal to the Department of History (Incorporating Archaeology Unit), and lastly preparing field equipments.

4.6 Field Research Methods

This category includes methods used in collecting data, conducting preliminary field analyses and site mapping. Data collection methods included surface collections, excavations, and ethnographic inquiries. Mapping included taking GPS readings for location of sites and contour mapping as specified below. Since the methods varied from site to site, the presentation here is also given according to sites.

4.6.1 Ngongwa Site

Ngongwa is located in Kalenga ward in Mkoga village, five kilometres east of Kalenga-Mkwawa museum. The reasons for its inclusion in the study have been provided in section 4.5 of this chapter.

Data collection at this site was done through surface collection, excavation, and interviews as well as focused group discussion. Before data collection, Datum Point

(DP) was established using 3D GPS Location with 10 satellites receptions. The datum point was established at latitude $07^{0}46'$ 50.1" S and longitude 035^{0} 37' 21.2" E next to a big stone, south of the site. The point is also 60 metres from a cactus tree, a unique species at the site. The cactus, which is 184^{0} south of DP, is located at latitude 07^{0} 46' 52.9" S and longitude 035^{0} 37' 21.1" E. The next task was mapping of the site using a transit machine (Plate 4.11) and a rod (Plate 4.12) with a view to produce a contour map of the site (Figure 4.3) with all important features indicated.

Plate 4.11: Transit machine

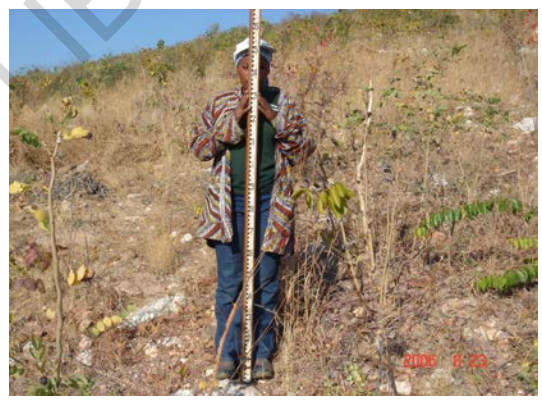
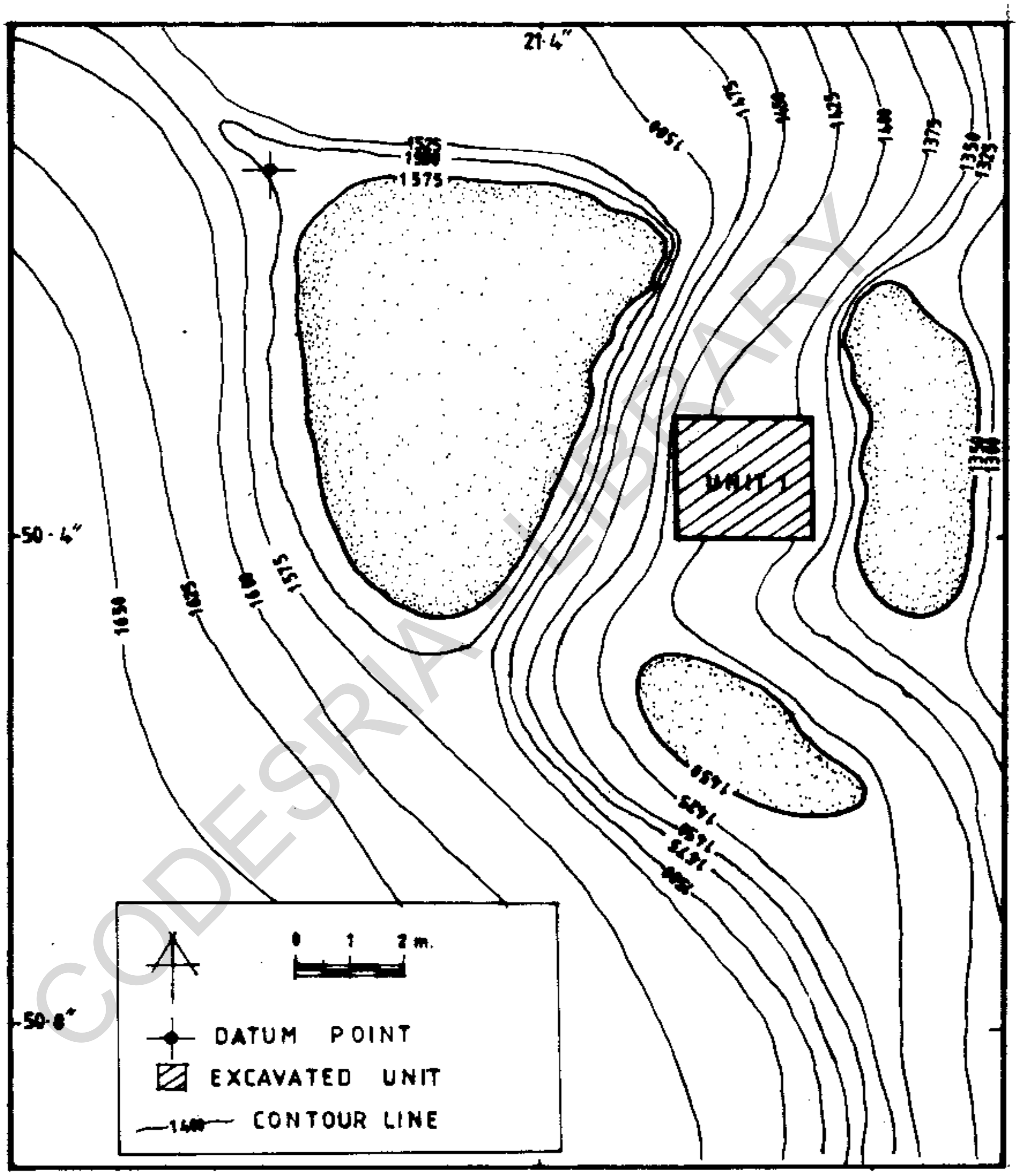


Plate 4.12: Transit Machine Rod

Figure 4.3: Contour Map of Ngongwa Site



The next task at Ngongwa involved surface collection of data at one of the three slag piles. This pile was larger than the other two and statistically constituted an area of material equivalent to 60 percent. The aim here was to collect 100 percent of materials constituting the pile. I collected about 90 percent of materials from the pile. The remaining couldn't be collected because they were deeply buried fused with the matrix (clay soil).

Preliminary analyses continued parallel with collection. These included sorting the materials into broad categories of slag, tuyeres, furnace walls, and potsherds; and identifying main categories of Ngongwa slag with the purpose of examining their physical properties. Attribute analyses focused on slag that could be easily examined in the field. Slag samples that needed close examination were bagged for laboratory analyses in Dar es Salaam, at the Archaeology Unit. Furnace walls (Plate 4.13) and tuyeres were counted and weighed and then left at the site.

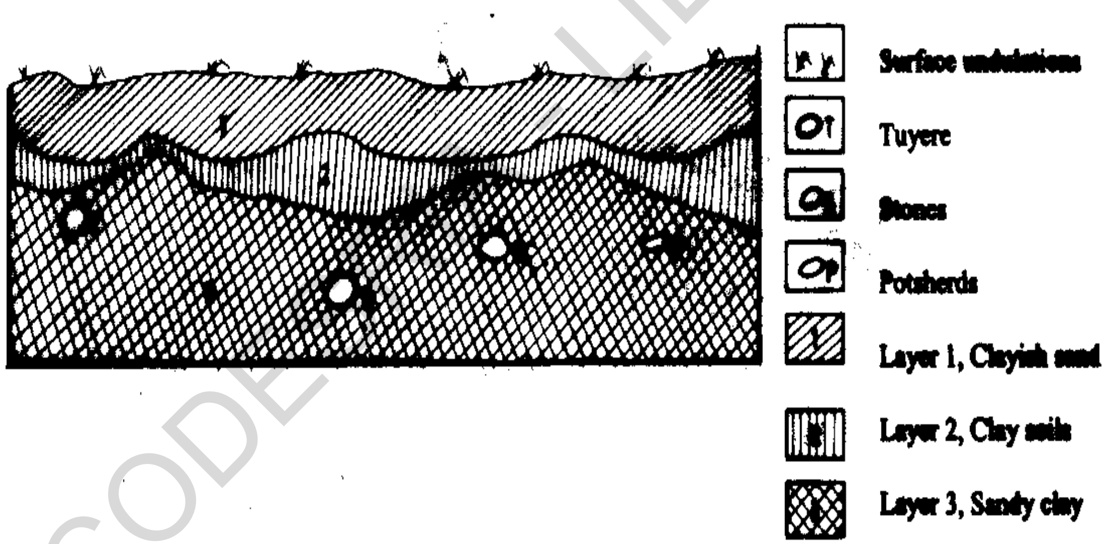
Plate 4.13: Ngongwa Furnace Walls

Excavation started after surface data collection had begun. At this point, the three activities, namely surface collection, analysis, and excavation were done simultaneously. Excavation unit was opened. The unit, which was named Unit 1 because the site hadn't been excavated before, measured 2.5m by 2.5m. It was oriented north-south. It was established at the centre of the three piles as it was thought that a superstructural furnace could have been there in addition to the bowl furnaces that were already exposed on the surface (See Plate 4.3). In addition to that expectation, we also intended to retrieve furnace-base slag or cake slag that accumulates at the bottom of furnaces. The North-East corner (latitude 07^0 46' 50.3" S and longitude 035^0 37' 21.5" E) was taken as a Sub Datum Point (SDP) of the unit. The other corners were at the following GPS readings: North-West latitude 07^0 46' 50.3" S and longitude 035^0 37' 21.5" E; South-East latitude 07^0 46' 50.5" S and longitude 035^0 37' 21.6" E; and South West latitude 07^0 46' 50.4" S and longitude 035^0 37' 21.4" E. Excavation proceeded by levels of 10 centimetres each. Excavation tools included trowels, a spirit level, a tape measure, hand hoes, pangas, sieves of two different sizes of 1 and 5 millimetres, and shovels. Excavation was accomplished within six days when a sterile layer was reached. Materials retrieved included cake slag and other types of slag, tuyeres (Plate 4.14), furnace walls, pottery, and a lot of charcoal pieces, three big samples of which were bagged for dating. At the end of this activity, floor plan and soil profile of northern wall (most representative wall) were drawn (Figure 4.4). Photographs were taken. Backfilling was done (Plate 4.15) when every material had been recorded.

Plate 4.14: Ngongwa Tuyeres

Plate 4.15: Backfilling Activity

Figure 4.4: Wall Profile of Unit 1, Ngongwa Site



The next task was to search for basic information about the site, for instance why was it there at the slopes of the mountain? Also we had to find the source of ore, water and fuel for the smelters. This required an ethnographic study which involved interviews, observations and a focused group discussion (FGD) (Plate 4.16).

Plate 4.16: Interviewees

4.6.2 Msete Site

Msete is located in Msete village, Hagafilo Division and Ward, Njombe District, Iringa Region. It is south east of Njombe town, which is a distance of 12 kilometres via Hagafilo. The reasons for its selection in the study have been presented in section 4.5 of this chapter.

Msete is a smelting site with two furnaces still standing: one at latitude 09^{0} 22' 25.6" S and longitude 034^{0} 49' 56.0" E (see Plate 4.5) and the other at latitude 09^{0} 22' 23.7" S and longitude 034^{0} 49' 58.9" E (see Plate 4.6). The furnaces, which are obstructed by tall trees coupled with tall grasses, are located along the slopes of Ngengedu River valley. The first thing here was to measure diameters, height, and take photographs. Furnace 1 was sampled to represent the other one as it was a complete one with slag inside and outside. Excavation, using a trowel, was conducted inside furnace 1 in order to collect slag. Surface collection done outside the furnace yielded slag, tuyeres and pottery. There was not much slag from outside the furnace probably because of erosion as the furnace is located on a steep slope and only ten metres from the river near the water falls (Plate 4.17). About one hundred metres east of furnace 1, there were concentrations of slag mixed with tuyeres and furnace rubble indicative of a smelting location. All of these (100%) were collected for analysis. Some slag which needed further laboratory examination was bagged and taken back to Dar es Salaam. Furnace walls, pottery and iron material were counted and weighed and left *in situ.*

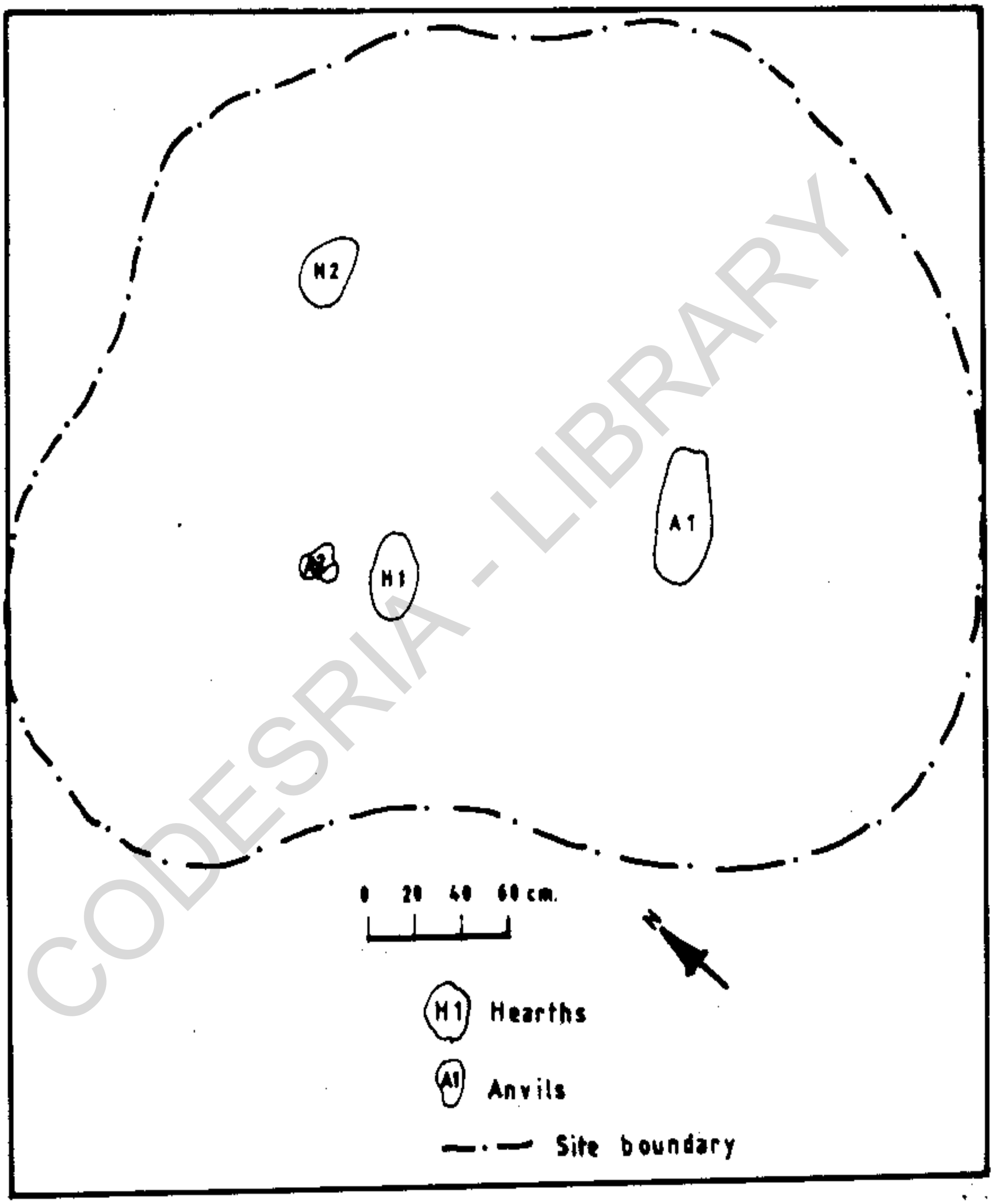
Plate 4.17: Ngengedu Waterfalls

4.6.3 Nundu Site

Nundu is located in Nundu village. This is an incontrovertible smithing site located about 150m southwest of Msete site. The two are separated by Ngengedu River. It is located at a hill top at an elevation of 1840 metres above mean sea level, latitude 09^{0} 22' 26.5" S and longitude 034^{0} 50' 00.8" E. It is about 150 metres northeast of furnace 1. In order to do some surface collections, the area was first cleared using hoes and pangas. A surface collection yielded lots of smithing slag, some tuyeres, iron, pottery, charcoal and two smithing hearths. The site was then sketched (Figure 4.5) and photographed (Plate 4.18). Attribute analyses of the slag were done in the Archaeology Unit laboratory at the University of Dar es Salaam. Iron, pottery, and charcoal were counted and weighed *in situ.*

Plate 4.18: Nundu Smithing Industry

Figure 4.5: Sketch Map of Nundu Site



4.6.4 Mpembani Site

The modern smithing site of Mpembani is located in Tumbe constituency, Northern Pemba. It consists of two forges referred to here as 1 and 2 (see Plates 4.1 and 4.2). Data collection at this site involved surface collections, excavation and ethnographic inquiries. Surface data were collected from both forges. Forge 1 was sampled for excavation. Before excavation, the forge was sketched to identify the specific location the smithing hearth, anvil, and the unit itself (Figure 4.6). A test pit was established oriented north-south, measuring 1 metre by 0.5 metres (Plate 4.19). The excavation followed arbitrary levels of 5 centimetres. The aim here was to find the depth and variation of metallurgical materials through time. Excavation tools included trowels, a sieve of 5 millimetres, a spirit level, tape measure, bags, and dust pans. Because the soil was wet and sticky, mixed with scale-slag, it was difficult to screen and hence I decided to take the excavated soil back to the Camp for screening using water. After excavation I drew a wall profile of the northern wall (Figure 4.7) and backfilled the unit. The soil that was taken to the camp was screened and the materials obtained were dried and afterwards sorted according to types. The materials included slag, glass, pottery, iron and beads. While slag and tuyeres were bagged for laboratory analyses in Dar es Salaam, the other materials were counted and weighed and left in Pemba.

Figure 4.6: Sketch Map of Mpembani Forge 1 Site

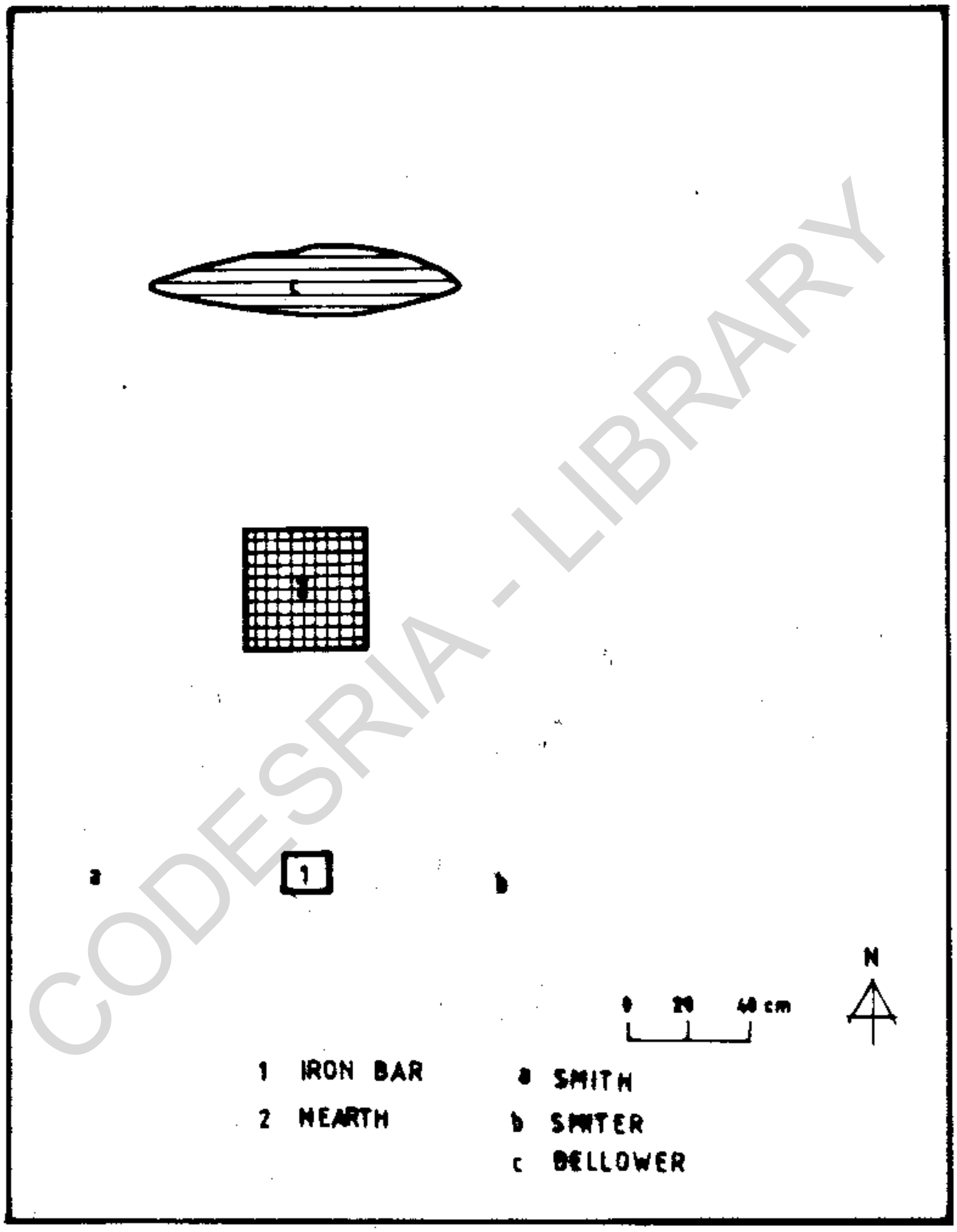
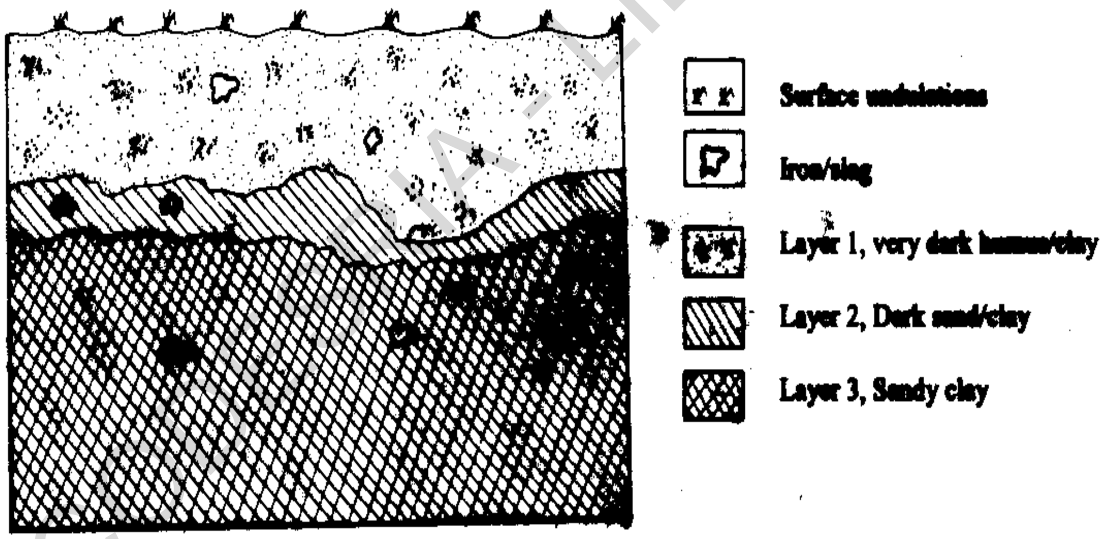


Plate 4.19: Mpembani Unit 1

Figure 4.7: Wall Profile of Unit 1, Mpembani Site



Interviews were done for two days; one Friday evening and one Sunday. The black smiths, who included fathers and sons, were interviewed in order to understand the origins of iron technology in the area, sources of raw materials, number of people in a forge and functions, smithing season, importance of iron working and types of tools produced. This was accompanied by observation of the activity itself and the way slag is produced (For data and interpretation see Chapter Seven, section 7.5).

4.6.5 Tumbe Site

This is an old site in Northern Pemba. It has been studied by Pemba Archaeological Project since 2002 (LaViolette *et al.* 2002). The analyzed data for July 2002 and July 2004 have been reported by Bertram Mapunda (Mapunda 2006). This means, Tumbe information used in this work comes largely from Mapunda (2006).

4.7 Laboratory Techniques

Laboratory works included careful examination of slag that had not been analysed in the field to determine their physical attributes such as shape, magnetism, and color. Tools used in the laboratory included vernier callipers, digital camera, bar magnet, measuring scales and a laptop computer.

4.8 Summary

This chapter has explored all methods employed in producing this work. It has provided the relevance and rationale of the methods from the initial stage to the end. Each site has been examined separately in order to produce a comprehensive and quality form of information. The following two chapters will focus on research findings.

CHAPTER FIVE

PRESENTATION AND ANALYSIS OF SMELTING SLAG

5.1 Preamble

This chapter provides data presentation and analyses with a focus upon smelting slag from Ngongwa and Msete sites. The chapter starts with an inventory (Table 5.1 and 5.2) of all materials collected from the sites. This is followed by attribute analyses presented in form of tables. Focus is centered on physical attributes of slag. Data from smithing sites are presented separately (in Chapter Six). This is done for the purpose of enhancing the variation of the two types of slag and so facilitating the work of comparing the two types which is done in Chapter Seven.

5.2 Inventory

Table 5.1 presents the inventory of cultural materials collected from the smelting sites in terms of type and quantity while Table 5.2 shows the same cultural materials in terms of mass (in grams). Before attribute analysis, Ngongwa surface-collected slag amount to 15,959 and other cultural materials amount to 1,953. Msete surface-collected slag pieces amount to 2,457 with a total of 63 other non-slag materials. Ngongwa excavated slag amount to 1,216 while non-slag materials amount to 666. In terms of total smelting slag collected from the sites amount to 19,632, and other cultural material add up to 2,782. The weight of slag and other cultural materials from the two sites are shown in Table 5.2 as follows. Surface-collected slag pieces from Ngongwa weigh 191,481 grams and other cultural materials weigh 154,484 grams; surface-collected slag pieces from Msete weigh 175,822 grams with a total of 6,923 grams for other cultural materials. Excavated slag pieces from Ngongwa weigh 39,206 grams with a total of 12,842 grams for the other cultural materials. The total weight for smelting slag is 406,509 grams and 174,249.5 grams for non-slag from these sites.

Table 5.1: Inventory of Cultural Materials from Smelting Sites by Quantity

Site	Slag	Tuyere	Furnace Fragments	Metal Objects	Pottery	Charcoal	Stones Tools	Total
Ngongwa (S)	15959	2	1951	0		0	0	**17912**
Ngongwa(E)	2457	53	449	0	9	67	5	**3040**
Msete (S)	1216	136	2	2	6	0	0	**1362**
Total	**19632**	**191**	**2402**	**2**	**15**	**67**	**5**	**22314**

Table 5.2: Inventory of Cultural Materials from Smelting Sites by Weight (g)

Site	Slag	Tuyere	Furnace Fragments	Metal Objects	Pottery	Charcoal	Stones Tools	Total
Ngongwa (S)	191481	886	153598	0		0	0	**345965**
Ngongwa(E)	39206	1588	10385	0	218	51	600	**52048**
Msete (S)	175822	4600	631	1260	432	0	0	**182745**
Total	**406509**	**7074**	**164614**	**1260**	**650**	**51**	**600**	**580758**

Key:

S=Surface Collected Data; E=Excavated Data

5.3 Attribute Analysis of Smelting Slag

The analysis involves examination of physical properties of smelting metalliferous slag using Mapunda's (2006) model with modifications (See Appendix 1). Because some pieces shared physical attributes, they were put into compound samples and analyzed together as one. On account of sample lumping, the amount of analyzed slag (Tables 5.3-5.28) seems to be much less than the actual amounts (Tables 5.1 and 5.2). Ngongwa site, for example has 287 samples and Msete has 82. The detailed analysis is presented in Appendix 2.

5.3.1 Presentation and Analysis of Slag from Ngongwa Site

5.3.1.1 Volume

Volume (in cc) is the product of length, width and thickness. It is an appropriate physical property for differentiating smelting from smithing slag as it is more comprehensive than length, width or thickness alone. The details for length (cm), width (cm) and thickness (cm) are presented in Appendix 2. The volume has a median of 26.68 cc, mean of 356.42 cc and a standard deviation of 2262.72 cc. Based on these statistics, this study groups the entire volume range into three major classes: below the median, median-mean (or median) and above mean (above median). Table 5.3 below shows that 143 slag pieces are below the median class, 106 are in the median class and 38 slag pieces are above the median class. The first class is equivalent to 50 percent, the second is equivalent to 37 percent and the third class is equivalent to 13 percent of the total smelting slag. While the minimum value for volume is 0.10 cc, the maximum value for Ngongwa slag is 35268.31 cc.

Table 5.3: Volume Classes of Ngongwa Slag, Quantity and Percent

Class	Class Interval (cc)	Quantity	Percent
Below Median	0-26.67	143	50
Median	26.68-356.42	106	37
Above Mean	356.43-35268.31	38	13
Total		**287**	**100**

5.3.1.2 Mass

Principally, mass is obtained by multiplying volume and density. Because the density was to be calculated, mass was obtained in grams by weighing slag pieces on a measuring scale. The mass of slag from Ngongwa has a median of 135.2 g, mean of 772.42 g and a standard deviation of 1938.97 g. Based on these statistics, the entire mass range (from minimum of 0.3 g to maximum of 25000 g) is divided into three groups, namely below the median, median and above median. Table 5.4 below shows that 143 slag pieces are below the median class, 72 are in the median class and 72 pieces of slag are above the median class. The first class is equivalent to 50 percent, the second is equivalent to 25 percent and the third class is equivalent to 25 percent of the total slag pieces from Ngongwa site.

Table 5.4: Mass Classes of Smelting Slag, Quantity and Percent

Class	Class Interval (in g)	Quantity	Percent
Below Median	0-135.19	143	50
Median	135.20-772.42	72	25
Above Median	772.43-25000	72	25
Total		**287**	**100**

5.3.1.3 Density

Density (in g/cc) is a ratio of volume and mass of a substance. Because volume and mass had been obtained, density was obtained by dividing the volume and the mass of slag. Smelting slag from Ngongwa site has a median of 2.99 g/cc, mean of 190.94g/cc and a standard deviation of 2195.45 g/cc. Based on these statistics, the entire range for density of slag is divided into three classes, namely below the median, median and above median. Table 5.5 shows that 184 slag are below the median class; 74 are in the median class and 112 slag pieces are above the median class. The quantity for the first class is equivalent to 50 percent. While the second is equivalent to46 percent, the last is equivalent to 4 percent. The minimum value for density of slag from Ngongwa is 0.16 g/cc while the maximum value is 36274.02 g/cc (See Appendix 2).

Table 5.5: Density Classes of Ngongwa Slag, Quantity and Percent

Class	Class Interval (in g/cc)	Quantity	Percent
Below Median	0-2.98	142	50
Median	2.99-190.94	133	46
Above Median	190.95-26274.51	12	4
Total		**287**	**100**

5.3.1.4 Morphology

Morphology refers to shape of the slag. Table 5.6 below presents 26 morphological variants of slag from Ngongwa site. Each variant is presented in terms of its quantity and percent of the total smelting slag. From the total amount of slag analyzed, 153 pieces of slag are amorphous (A) equivalent to 53 percent, 38 slag are cake-like (CK) (Plate 5.1) equivalent to 13 percent, 13 slag are droplets (D) (Plate 5.2) equivalent to 5 percent, 12 slag are pyramidal (P) (Plate 5.3) equivalent to 4 percent, 10 slag are blocky-cake like (BCK) equivalent to 3 percent, 9 slag are hemisphere (H) (Plate 5.4) equivalent to 3 percent, 6 slag are L-shaped (L) (Plate 5.5) and bean-like (BE) (Plate 5.6) equivalent to 2 percent, 4 slag are radial (R)and short sticks (SS) (Plate 5.7) equivalent to 1 percent, 3 slag pieces are triangle (TR), 8-shaped (8) (Plate 5.8), mold (M) (Plate 5.9), cylinder (C), and Y-shaped (Y) (Plate 5.10) equivalent to 1 percent, 2 pieces of slag are slag-tuyere (ST), flow slag (FL), fingers like slag (FN) (Plate 5.11), V-shaped (V) (Plate 5.12), S-shaped (S) (Plate5.13) and T-shaped (T) (Plate 5.14), equivalent to 1 percent, and one piece of slag is animal-like (AN) (Plate 5.15), curved sticks (CS) (Plate 5.16), fish like slag (FS) (Plate 5.17), X-shaped (X) (Plate 5.18) and dendritic (DE) all by below 1 percent.

Table 5.6: Morphology of Ngongwa Slag

S/No.	Type of Morphology	Symbol	Plate No.	Frequency	Percent
1	Amorphous	A		153	53
2	Cake-like	CK	5.1	38	13
3	Droplets	D	5.2	13	5
4	Pyramidal	P	5.3	12	4
5	Blocky-cake like	BCK		10	3
6	Hemisphere	H	5.4	9	3
7	Bean-like	BE	5.6	6	2
8	L-shaped	L	5.5	6	2
9	Radial	R		4	1
10	Short sticks	SS	5.7	4	1
11	Triangle	TR		3	1
12	8-shaped	8	5.8	3	1
13	Mold	M	5.9	3	1
14	Cylinder	C		3	1
15	Y-shaped	Y	5.10	3	1
16	Slag-Tuyere	ST		2	1
17	Flow	FL		2	1
18	Fingers-like	FN	5.11	2	1
19	V-shaped	V	5.12	2	1
20	S-shaped	S	5.13	2	1
21	T-shaped	T	5.14	2	1
22	Curved sticks	CS	5.16	1	0
23	Dendtric	DE		1	0
24	Fish-like	FS	5.17	1	0
25	Animal-like	AN	5.15	1	0
26	X-shaped	X	5.18	1	0
Total		**26**		**287**	**100.0**

Plate 5.1: Cake Slag

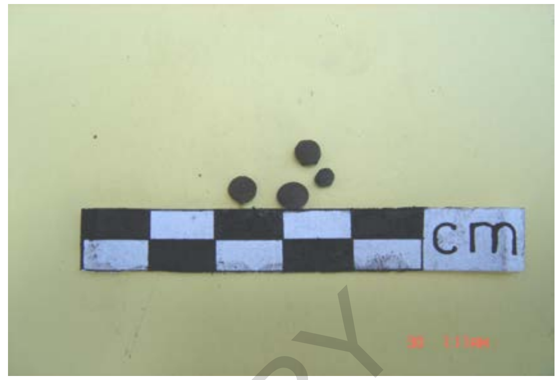


Plate 5.2: Droplets Slag

Plate 5.3: Pyramidal Slag

Plate 5.4: Hemisphere Slag

Plate 5.5: L-shaped Slag

Plate 5.6: Bean Slag

Plate 5.7: Short Sticks Slag

Plate 5.8: 8-shaped Slag

Plate 5.9: Mold Slag

Plate 5.10: Y-shaped Slag

Plate 5.11: Fingers-like Slag

Plate 5.12: V-shaped Slag

Plate 5.13: S-shaped Slag

Plate 5.14: T-shaped Slag

Plate 5.15: Animal-like Slag

Plate 5.16: Curved Sticks Slag

Plate 5.17: Fish-like Slag

Plate 5.18: X-shaped Slag

5.3.1.5 Thermal Condition

Table 5.7 presents thermal conditions of smelting slag from Ngongwa arranged according to frequency or quantity and percentage. Out of slag collected, 143 are flow slag (F) amounting to 50 percent, 112 are melted slag (M) amounting to 39 percent, 28 are partially reduced slag (R) amounting to 10 percent, 3 are conglomeration slag (C) amounting to 1 percent and one is unreduced amounting to less than 1 percent.

Table 5.7: Thermal Conditions of Ngongwa Slag

S/No.	Thermal Condition	Symbol	Frequency	Percent
1	Flow	F	143	50
2	Melted	M	112	39
3	Reduced Partially	R	28	10
4	Conglomeration	C	3	1
5	Unreduced	N	1	0
Total		**5**	**287**	**100**

5.3.1.6 Luster

The analysis shows that smelting slag pieces from Ngongwa site have a metallic luster (M) by 100 percent, which indicates that all the analyzed slag is purely metallic.

5.3.1.7 Porosity

Table 5.8 shows that 239 slag pieces equivalent to 83 percent are very low porous (VL), 44 pieces of slag equivalent to 15 percent are low porous (L), and 4 pieces of slag 5 slag equivalent to 1 percent are not porous (N).

Table 5.8: Porosity of Ngongwa Slag

S/No.	Rate of Porosity	Symbol	Frequency	Percent
1	Very Low	VL	239	83
2	Low	L	44	15
3	Nil	N	4	1
Total		**3**	**287**	**100**

5.3.1.8 Magnetism

Table 5.9 presents ferromagnetic property of smelting slag according to which, 74 percent equivalent to 212 slag pieces show low magnetism (L), 11 percent equivalent to 33 slag pieces show no magnetism (N), 10 percent equivalent to 29 slag pieces show medium magnetism (N), 3 percent equivalent to 9 slag pieces show high magnetism (H), and 1 percent equivalent to 4 slag pieces show very low magnetism (VL).

Table 5.9: Magnetism of Ngongwa Slag

S/No.	Rate of Magnetism	Symbol	Frequency	Percent
1	Low	L	212	74
2	Nil	N	33	11
3	Medium	M	29	10
4	High	H	9	3
5	Very Low	VL	4	1
Total		**5**	**287**	**100**

5.3.1.9 Color

Table 5.10 shows 20 combinations of colors for smelting slag from Ngongwa site. The combinations are put in order of their frequency and percentage: 61 slag pieces are reddish gray (RG) amounting to 21 percent, 76 slag pieces are brownish gray (BG) amounting to 20 percent, 49 slag pieces are dark gray (DG) amounting to 17 percent, 39 slag pieces are reddish brown (RB) amounting to 14 percent, 20 slag pieces are light gray (LG) amounting to 7 percent, 18 slag pieces are yellowish gray (YG) amounting to 6 percent, 8 slag pieces are grayish brown (GB) amounting to 3 percent,6 slag pieces are dark brown (DB), yellowish red (YR) and dark reddish brown (DRB) amounting to 2 percent, 3 slag pieces are gray (G) and reddish yellow (RY) amounting to 1 percent, 2 slag pieces are orange gray (OG) and yellowish brown (YB) all amounting to 1 percent, and lastly 1 slag piece is brown (B), brownish red (BR), brownish yellow (BY), light brownish gray (LBG) light reddish gray (LRG) and very dark gray (VDG) each amounting to less than 1 percent.

Table 5.10: Colors of Ngongwa Slag

S/No.	**Type of Color**	**Symbol**	**Frequency**	**Percent**
1	Reddish Gray	RG	61	21
2	Brownish Gray	BG	58	20
3	Dark Gray	DG	49	17
4	Reddish Brown	RB	39	14
5	Light Gray	LG	20	7
6	Yellowish Gray	YG	18	6
7	Grayish Brown	GB	8	3
8	Dark Brown	DB	6	2
9	Yellowish Red	YR	6	2
10	Dark Reddish Brown	DRB	6	2
11	Gray	G	3	1
12	Reddish Yellow	RY	3	1
13	Orange Gray	OG	2	1
14	Yellowish Brown	YB	2	1
15	Light Reddish Gray	LRG	1	0
16	Brownish Red	BR	1	0
17	Brownish Yellow	BY	1	0
18	Brown	B	1	0
19	Light Brownish Gray	LBG	1	0
20	Very dark Gray	VDG	1	0
Total		**20**	**287**	**100**

5.3.1.10 Inclusions

Table 5.11 presents inclusions of smelting slag from Ngongwa site. It is shown that 273 slag pieces (95%) are free of inclusions, 7 pieces (2%) have sand inclusions (SA), 3 slag pieces (1%) have charcoal inclusions (CH), and 2 pieces of slag (1%) have tuyeres inclusions (TU) and wood inclusions (WO).

Table 5.11: Inclusions of Ngongwa Slag

S/No.	Inclusion Material	Symbol	Frequency	Percent
1	Nil	N	273	95
2	Sand	SA	7	2
3	Charcoal	CH	3	1
4	Tuyeres	TU	2	1
5	Wood	WO	2	1
Total		**5**	**287**	**100**

5.3.1.11 Impressions

Table 5.12 shows kinds of impressions found in smelting slag from Ngongwa site. While 185 slag pieces equivalent to 64 percent show no clear impressions (M/), 55 slag pieces equivalent to 19 percent show no impressions (N). Also, 43 slag pieces equivalent to 15 percent show ground floor impressions (GR), and 2 slag pieces equivalent to 1 percent show flow marks (FL) and wood (WO) impressions.

Table 5.12: Impressions of Ngongwa Slag

S/No.	Impression Materials	Symbol	Frequency	Percent
1	Not Identified	M/	185	64
2	None	N	55	19
3	Ground	GR	43	15
4	Flow Marks	FL	2	1
5	Wood	WO	2	1
Total		**5**	**287**	**100**

5.3.1.12 Fragmentation or Breakage

Table 5.13 shows the breakage patterns of Ngongwa slag. Out the collected slag, seventy seven slag pieces (27%) are broken three sides (3), 75 slag pieces (26%) are broken two sides (2), 49 slag pieces (17%) are broken one side (1), 33 slag pieces (11%) are broken four sides (4), 28 slag pieces (10%) are complete, 18 slag pieces (6%) are broken five sides (5) and 7 slag pieces (2%) are broken six sides (6).

Table 5.13: Fragmentation of Ngongwa Slag

S/No.	Rate of Fragmentation	Symbol	Frequency	Percent
1	Three Sides Broken	3	77	27
2	Two Sides Broken	2	75	26
3	One Side Broken	1	49	17
4	Four Sides Broken	4	33	11
5	Not Broken	0	28	10
6	Five Sides Broken	5	18	6
7	All Sides Broken	6	7	2
Total		**7**	**287**	**100**

5.3.1.13 Weathering

This property includes oxidation and rusting of smelting slag. Table 5.14 presents the levels of weathering processes on smelting slag. Eighty one pieces of slag which is equivalent to 28 percent are affected one side (1). While 70 pieces of slag which is equivalent to 24 percent are affected two sides (2), 65 pieces of slag which is equivalent to 23 percent are not affected (0). Thirty six pieces of slag which is equivalent to 13 percent are affected three sides (3), 26 pieces of slag which is equivalent to 9 percent are affected four sides (6), 8 pieces of slag which is equivalent to 3 percent are affected five sides (5), and 1 piece of slag which is equivalent to less than one percent is affected six sides (6).

Table 5.14: Weathering of Ngongwa Slag

S/No.	Rate of Weathering	Symbol	Frequency	Percent
1	One Side Oxidized	1	81	28
2	Two Sides Oxidized	2	70	24
3	Non-Oxidized	0	65	23
4	Three Sides Oxidized	3	36	13
5	Four Sides Oxidized	4	26	9
6	Five Sides Oxidized	5	8	3
7	All Sides Oxidized	6	1	0
Total		**7**	**287**	**100**

5.3.1.14 Raw Material

This attribute looks for source materials for slag, which include mixture materials, ceramic, and gangue. The analysis of source material attribute for smelting slag from Ngongwa shows that 286 slag pieces are made up of a mixture (M) of raw material, which is equivalent to 99 percent and rarely would be made up of tuyeres because only 1 piece of slag is shown with tuyeres (TU) raw materials.

5.3.1.15 Surface Conditions

Table 5.15 presents types of surface conditions of smelting slag from Ngongwa site. The data show that 103 pieces of slag equivalent to 36 percent have rough surface (R), 91 pieces of slag equivalent to 32 percent have smooth surface (S), 55 pieces of slag equivalent to 19 percent have somehow smooth surface (SS), 25 pieces of slag equivalent to 9 percent have slippery surface (SL), 9 pieces of slag equivalent to 3 percent have very rough surface (VR), and 4 pieces of slag equivalent to 1 percent have somehow rough (SR).

Table 5.15: Surface Conditions of Ngongwa Slag

S/No.	Surface Condition	Symbol	Frequency	Percent
1	Rough	R	103	36
2	Smooth	S	91	32
3	Somehow Smooth	SS	55	19
4	Slippery	SL	25	9
5	Very Rough	VR	9	3
6	Somehow Rough	SR	4	1
Total		**6**	**287**	**100**

5.3.2 Presentation and Analysis of Slag from Msete Site

5.3.2.1 Volume

The volume of slag from Msete site has a median of 111.49 cc, mean of 553.20 cc and a standard deviation of 892.62 cc. Based on these statistics, this study groups the entire volume range into three major classes: below the median, median-mean (or median) and above mean (above median). Table 5.16 shows that 41 slag pieces are below the median class, 15 are in the median class and 26 are above the median class. The first class is equivalent to 50 percent, the second is equivalent to 18 percent and the third class is equivalent to 32 percent of the total smelting slag from Msete site. While the minimum value for volume is 0.04 cc, the maximum value for Ngongwa slag is 4410 cc.

Table 5.16: Volume Classes of Msete Slag, Quantity and Percent

Class	Class Interval (cc)	Quantity	Percent
Below Median	0-111.48	41	50
Median	111.49-553.20	15	18
Above Mean	553.21-4410.0	26	32
Total		**82**	**100**

5.3.2.2 Mass

The mass of slag from Msete has a median of 1239.75 g, mean of 2144.17 g and a standard deviation of 2693.77 g. Based on these statistics, the entire mass range (from minimum of 0.10 g to maximum of 14100 g) is divided into three groups, namely below the median, median and above median. Table 5.17 below shows that 41 slag pieces are below the median class, 13 are in the median class and 28 pieces of slag are above the median class. The first class is equivalent to 50 percent, the second is equivalent to 16 percent and the third class is equivalent to 34 percent of the total slag pieces from Msete site.

Table 5.17: Mass Classes of Msete Slag, Quantity and Percent

Class	Class Interval (in g)	Quantity	Percent
Below Median	0-1239.74	41	50
Median	1239.75-2144.17	13	16
Above Median	2144.18-14100.0	28	34
Total		**82**	**100**

5.3.2.3 Density

Smelting slag from Msete site has a median of 2.79 g/cc, mean of 107.81 g/cc and a standard deviation of 487.43 g/cc. Based on these statistics, the entire range for density of slag is divided into three classes, namely below the median, median and above median. Table 5.18 shows that 41 pieces of slag are below the median class; 34 are in the median class and 7 slag pieces are above the median class. The quantity for the first class is equivalent to 50 percent. While the second is equivalent 41 percent, the last is equivalent to 9 percent. The minimum value for density of slag from Msete is 0.13 g/cc while the maximum value is 3125.00 g/cc (See Appendix 2).

Table 5.18: Density Classes of Msete Slag, Quantity and Percent

Class	Class Interval (in g/cc)	Quantity	Percent
Below Median	0-2.78	41	50
Median	2.79-107.81	34	41
Above Median	107.82-3125.0	7	9
Total		**82**	**100**

5.3.2.4 Morphology

Table 5.19 presents 16 morphological aspects of slag from Msete site in terms of quantity and percent. From the total amount of slag collected, 39 pieces of slag are amorphous (A) equivalent to 48 percent, 11 are cake-like (CK) (see Plate 5.1) equivalent to 13 percent, 7 pieces of slag are slag-tuyere (ST) (Plate 5.6) equivalent to 8 percent, 5 slag pieces are pyramidal (P) (see Plate 5.3) equivalent to 6 percent, 4 pieces of slag are droplets (D) (Plate 5.2) equivalent to 5 percent, 3 slag pieces are L-shaped (L) (see Plate 5.5) equivalent to 4 percent, 2 slag pieces are hemisphere (H) (see Plate 5.4), short sticks (SS) (Plate 5.8) and blocky-amorphous (BA) equivalent to 2 percent, 1 slag piece is 4-shaped (4) (Plate 5.19), blocky-pyramidal (BP), fingers like slag (FN), K-shaped (K) (Plate 5.20), S-shaped (S) (see Plate5.15), tuyere-slag (TS) and Y-shaped (Y) (see Plate 5.10) equivalent to 1 percent.

Table 5.19: Morphology of Msete Slag

S/No.	Type of Morphology	Symbol	Plate No.	Frequency	Percent
1	Amorphous	A		39	48
2	Cake like	CK	5.1	11	13
3	Slag-tuyere	ST	5.11	7	8
4	Pyramidal	P	5.3	5	6
5	Droplet	D	5.2	4	5
6	L-shaped	L	5.5	3	4
7	Hemisphere	H	5.4	2	2
8	Curved sticks	SS	5.7	2	2
9	Blocky-amorphous	BA		2	2
10	4-shaped	4	5.19	1	1
11	Blocky-pyramidal	BP		1	1
12	Fingers-like	FN	5.1	1	1
13	K-shaped	K	5.20	1	1
14	S-shaped	S	5.15	1	1
15	Tuyere-slag	TS		1	1
16	Y-shaped	Y	5.10	1	1
Total		**17**		**82**	**100**

Plate 5.19: 4-shaped Slag

Plate 5.20: K-shaped Slag

5.3.2.5 Thermal Condition

Table 5.20 presents thermal conditions of smelting slag from Msete arranged according to frequency or quantity and percentage. Out of slag pieces collected, 50 are melted slag (M) amounting to 61 percent, 22 are flow slag (F) amounting to 27 percent, 6 are partially reduced slag (R) amounting to 7 percent, and 4 are conglomeration slag (C) amounting to 5 percent.

Table 5.20: Thermal Conditions of Msete Slag

S/No.	Thermal Condition	Symbol	Frequency	Percent
1	Melted	M	50	61
2	Flow	F	22	27
3	Partially Reduced	R	6	7
4	Conglomeration	C	4	5
Total		**4**	**82**	**100**

5.3.2.6 Luster

The analysis shows that smelting slag pieces from Msete have a metallic luster (M) by 100 percent, which indicates that all the analyzed slag pieces are purely metallic.

5.3.2.7 Porosity

Table 5.21 shows that 50 slag pieces equivalent to 61 percent are very low porous (VL), 29 pieces of slag equivalent to 35 percent are low porous (L), 2 pieces of slag equivalent to 3 percent are medium porous (M), and 1 piece equivalent to 1 percent is not porous (N).

Table 5.21: Porosity of Msete Slag

S/No.	Rate of Porosity	Symbol	Frequency	Percent
1	Very Low	VL	50	61
2	Low	L	29	35
3	Medium	M	2	3
4	Nil	N	1	1
Total		**4**	**82**	**100**

5.3.2.8 Magnetism

Table 5.22 presents ferromagnetic property of smelting slag according to which, 54 slag pieces (65%) show low magnetism (L), 13 slag pieces (16%) show medium magnetism (M), 11 slag pieces (13%) show high magnetism (H), 2 slag pieces (3%) show no magnetism (N) and very low magnetism (VL).

Table 5.22: Magnetism of Msete Slag

S/No.	Rate of Magnetism	Symbol	Frequency	Percent
1	Low	L	54	65
2	Medium	M	13	16
3	High	H	11	13
4	Nil	N	2	3
5	Very Low	VL	2	3
Total		**5**	**82**	**100**

5.3.2.9 Color

Table 5.23 shows 20 combinations of colors for smelting slag from Msete. The combinations are put in order of their frequency and percentage: 23 slag pieces are dark gray (DG) amounting to 28 percent, 18 slag pieces are reddish gray (RG) and brownish gray (BG) all amounting to 22 percent, 7 slag pieces are dark brown (DB) amounting to 9 percent, 5 slag pieces are reddish brown (RB) amounting to 6 percent, 4 slag pieces are yellowish brown (YB) and yellowish gray (YG) all amounting to 5 percent, and one piece is grayish brown (GB), light gray (LG) and olive reddish gray (ORG) all amounting to 1 percent.

Table 5.23: Colors of Msete Slag

S/No.	Type of Color	Symbol	Frequency	Percent
1	Dark Gray	DG	23	28
2	Reddish Gray	RG	18	22
3	Brownish Gray	BG	18	22
4	Dark Brown	DB	7	9
5	Reddish Brown	RB	5	6
6	Yellowish Brown	YB	4	5
7	Yellowish Gray	YG	4	5
8	Grayish Brown	GB	1	1
9	Light Gray	LG	1	1
10	Olive Reddish Gray	ORG	1	1
Total		**10**	**82**	**100**

5.3.2.10 Inclusions

Table 5.24 presents inclusions of smelting slag from Msete site. It is shown that 77 slag pieces (94%) are free of inclusions, 3 pieces (4%) have tuyeres inclusions (TU), and one piece (1%) has sand inclusions (SA) and stone inclusions (ST).

Table 5.24: Inclusions of Msete Slag

S/No.	Inclusion Material	Symbol	Frequency	Percent
1	Nil	N	77	94
2	Tuyere	TU	3	4
3	Sand	SA	1	1
4	Stone	ST	1	1
Total		**4**	**82**	**100**

5.3.2.11 Impressions

Table 5.25 shows kinds of impressions found in smelting slag from Msete site. While 61 slag pieces equivalent to 74 percent show no clear impressions (M/), 14 slag pieces equivalent to 17 percent show no impressions (N). Also, 4 slag pieces equivalent to 5 percent show ground floor impressions (GR), 2 slag pieces equivalent to 3 percent show flow marks (FL) and one piece has tuyere impressions (TU).

Table 5.25: Impressions of Msete Slag

S/No.	Impression Materials	Symbol	Frequency	Percent
1	Not Identified	M/	61	74
2	None	N	14	17
3	Ground Floor	GR	4	5
4	Flow Marks	FL	2	3
5	Tuyere	TU	1	1
Total		**5**	**82**	**100**

5.3.2.12 Fragmentation or Breakage

Table 5.26 shows the breakage patterns of Msete slag. Out the collected slag pieces, 27 slag pieces (33%) are broken two sides (2), 22 slag pieces (27%) are broken three sides (3), 17 slag pieces (21%) are broken one side (1), 11 slag pieces (13%) are broken four sides (4), 4 slag pieces (5%) are complete, and one piece is broken five sides (5).

Table 5.26: Fragmentation of Msete Slag

S/No.	Rate of Fragmentation	Symbol	Frequency	Percent
1	Two Sides Broken	2	27	33
2	Three Sides Broken	3	22	27
3	One Side Broken	1	17	21
4	Four Sides Broken	4	11	13
5	Not Broken	0	4	5
6	Five Sides Broken	5	1	1
Total		**6**	**82**	**100**

5.3.2.13 Weathering

Table 5.27 presents the levels of weathering processes on smelting slag from Msete site. Thirty four pieces of slag which is equivalent to 41 percent are affected one side (1). While 23 pieces of slag which is equivalent to 28 percent are affected two sides (2), 9 pieces of slag which is equivalent to 11 percent are affected three sides (3). Eight pieces of slag which is equivalent to 10 percent are not affected (0) while eight pieces of slag equivalent to 9 percent are affected four sides (4).

Table 5.27: Weathering of Msete Slag

S/No.	Rate of Weathering	Symbol	Frequency	Percent
1	One Side Oxidized	1	34	41
2	Two Sides Oxidized	2	23	28
3	Three Sides Oxidized	3	9	11
4	Non-oxidized	0	8	10
5	Four Sides Oxidized	4	8	10
Total		**5**	**82**	**100**

5.3.2.14 Raw Material

The analysis of source material attribute for smelting slag shows that 81 slag pieces are made up of a mixture (M) of raw material, which is equivalent to 99 percent and rarely would be made up of tuyeres because only 1 slag is shown with tuyeres (TU) raw materials.

5.3.2.15 Surface Conditions

Table 5.28 presents types of surface conditions of smelting slag from Msete site. The data show that 34 pieces of slag equivalent to 42 percent have rough surface (R), 23 pieces of slag equivalent to 28 percent have somehow smooth surface (SS), 18 pieces of slag equivalent to 22 percent have smooth surface (S), 6 pieces of slag equivalent to 7 percent have slippery surface (SL), and one piece of slag equivalent to 1 percent has somehow rough (SR).

Table 5.28: Surface Conditions of Msete Slag

S/No.	Surface Condition	Symbol	Frequency	Percent
1	Rough	R	34	42
2	Somehow Smooth	SS	23	28
3	Smooth	S	18	22
4	Slippery	SL	6	7
5	Somehow Rough	SR	1	1
Total		**5**	**82**	**100**

5.4 Summary

This chapter has dealt with smelting data from Ngongwa and Msete sites, which have been presented in forms of texts and tables. The focus has been on physical attributes. The following table summarizes the findings from the two sites.

Table 5.29: Attribute Analysis from Ngongwa and Msete Sites

		Ngongwa Slag		Msete Slag		Average	
S/No.	**Attribute**	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
1	Volume (cc)	356	27	553	111.5	454.5	69.25
2	Mass (g)	772	135	2144	1240	1458	687.5
3	Density (g/cc)	191	3	108	3	149.5	3
		Mode	**Frequency**	**Mode**	**Frequency**	**Mode**	**Frequency**
4	Morphology	CK	153	CK	56	CK	11
5	Thermal Condition	F	143	M	50	F	96.5
6	Luster	M	287	M	82	M	184.5
7	Porosity	VL	239	VL	50	VL	144.5
8	Magnetism	L	212	L	54	L	133
9	Color	RG	61	DG	23	G	42
10	Inclusion	N	273	N	77	N	175
11	Impressions	M/	185	M/	61	M/	123
12	Fragmentation	3	77	2	27	2	52
13	Weathering	1	81	1	34	1	57.5
14	Source Material	M	286	M	81	M	183.5
15	Surface Conditions	R	103	R	34	R	68.5

CHAPTER SIX

PRESENTATION AND ANALYSIS OF SMITHING SLAG

6.1 Preamble

This chapter presents and analyses data from three smithing sites, namely Nundu, Mpembani and those from Tumbe as analyzed by Mapunda (2006). The chapter starts with an inventory (Table 6.1 and 6.2) of all materials collected from the first two sites. This is followed by attribute analyses presented in forms of tables. Focus is centered on physical attributes.

6.2 Inventory

While Table 6.1 presents the inventory of types of cultural materials in terms of type and quantity, Table 6.2 shows the same cultural materials in terms of their mass (in grams). Nundu surface collected slag amount to 679 and other non-slag materials amount to 112. Mpembani surface collected slag amount to 3,845 with a total of 119 other non-slag materials. Mpembani excavated slag amount to 3,779 with a total of 77 other cultural materials. In terms of total smithing slag collected from the sites amount to 8,303, and other non-slag materials add up to 308.

The weight for the amount of slag and other cultural materials for the sites are shown in Table 6.2 as follows. Nundu surface-collected slag pieces weigh 9558.5 grams with a total of 23,145.6 grams for other non-slag materials. Mpembani surface-collected slag pieces weigh 2637.7 grams and other non-slag materials weigh 1,130 grams. Mpembani excavated slag weigh 251.47 grams with a total of 1,074.6 grams for other cultural materials. The total weight for smithing slag is 12,447.67 grams and 25,350.2 grams for non-slag from these sites.

Table 6.1: Inventory of Cultural Materials from Smithing Sites by Quantity

Site	Slag	Tuyere	Metal Objects	Pottery	Charcoal	Stones Tools	Glass	Bead	Shell	**Total**
Nundu	679	73	13	4	13	9	0	0	0	**791**
Mpembani (S)	3845	0	111	2	0	0	6	0	0	**3964**
Mpembani (E)	3779	45	0	13	0	0	17	1	1	**3856**
Total	**8303**	**118**	**124**	**19**	**13**	**9**	**23**	**1**	**1**	**8611**

Table 6.2: Inventory of Cultural Materials from Smithing Sites by Weight (g)

Site	Slag	Tuyere	Metal Objects	Pottery	Charcoal	Stones Tools	Glass	Bead	Shell	**Total**
Nundu	9558.5	1400	386	100	25	21235	0	0	0	**32704**
Mpembani (S)	2637.7	0	705	124	0	0	301	0	0	**3767.7**
Mpembani (E)	251.47	853	0	137	0	0	34	1	5	**1281.1**
Total	**12447.7**	**2253**	**1091**	**361**	**25**	**21235**	**335**	**1**	**50**	**37798**

Key:

S=Surface Collected Data; E=Excavated Data

6.3 Attributes Analysis of Smithing Slag

The analysis involves examination of physical properties of smithing metalliferous slag using Mapunda's (2006) model with modifications (See Appendix 1). Because some pieces shared physical attributes, they were put into compound samples and analyzed together as one. On account of sample lumping, the amount of analyzed slag (Tables 6.3-6.28) seems to be much less than the actual amounts (Tables 5.1 and 5.2). Nundu site, for example has 57 samples and Mpembani has 106. The detailed-analysis is presented in Appendix 2.

6.3.1 Presentation and Analysis of Slag from Nundu Site

6.3.1.1 Volume

The volume of smithing slag from Nundu has a median of 2.00 cc, mean of 24.78 cc and a standard deviation of 63.92 cc. Based on these statistics, this study groups the entire volume range into three major classes: below the median, median-mean (or median) and above mean (or above median). Table 6.3 below shows that 28 slag pieces are below the median class, 19 are in the median class and 10 are above the median class. The first class is equivalent to 49 percent, the second is equivalent to 33 percent and the third class is equivalent to 18 percent of the total smelting slag. While the minimum value for volume is 0.001 cc, the maximum value for Nundu slag is 296.43 cc.

Table 6.3: Volume Classes of Smithing Slag, Quantity and Percent

Class	Class Interval (in cc)	Quantity	percent
Below Median	0-1.99	28	49
Median	2.0-24.78	19	33
Above Median	24.79-296.43	10	18
Total		**57**	**100**

6.3.1.2 Mass

The mass for smithing slag has a median of 27.50 g, mean of 203.35 g and a standard deviation of 470 g. Based on these statistics, the entire mass range is divided into below the median, median and above median classes. Table 6.4 shows that 33 slag pieces are below the median class, 16 are in the median class and 8 are above the median class. The first class is equivalent to 58 percent, the second is equivalent to 28 percent and the third class is equivalent to 14 percent of the total smithing slag. While the minimum mass is 0.10 g, the maximum mass is 2200.00 g.

Table 6.4: Mass Classes of Nundu Slag, Quantity and Percent

Class	Class Interval	Quantity	Percent
Below Median	0-27.49	33	58
Median	27.50-203.35	16	28
Above Median	203.36-2200	8	14
Total		**57**	**100**

6.3.1.3 Density

Smithing slag from Nundu site has a median of 7.40 g/cc, mean of 12.50 g/cc and a standard deviation of 23.40 g/cc. Based on these statistics, the entire range for density of slag is divided into three classes, namely below the median, median and above median. Table 6.5 shows that 30 slag pieces are below the median class; 12 are in the median class and 15 slag pieces are above the median class. The quantity for the first class is equivalent to 53 percent. While the second is equivalent to 21 percent, the last is equivalent to 26 percent. The minimum value for density of slag from Nundu is 0.50 g/cc while the maximum value is 164.58 g/cc (See Appendix 2).

Table 6.5: Mass Classes of Nundu Slag, Quantity and Percent

Class	Class Interval	Quantity	Percent
Below median	0-7.42	30	53
Median	7.43-12.56	12	21
Above Median	12.57-164.58	15	26
Total		**57**	**100**

6.3.1.4 Morphology

Table 6.6 presents morphological attributes of smithing slag in terms of quantity and percent. From the total amount of smithing slag collected, 33 slag pieces equivalent to 58 percent are amorphous (A), 11 pieces equivalent to 19 percent are scale-like (SC) (Plate 6.1), 9 pieces equivalent to 16 percent are droplets (D), 3 equivalent to 5 percent are cake-like (CK) (Plate 6.2), and one piece equivalent to 2 percent spear (SE) (Plate 6.3).

Table 6.6: Morphology of Nundu Slag

S/No.	**Type of Morphology**	**Symbol**	**Plate No.**	**Frequency**	**Percent**
1	Amorphous	A		33	58
2	Scale like	SC	6.1	11	19
3	Droplet	D		9	16
4	Cake like	CK	6.2	3	5
5	Spear like	SE	6.3	1	2
Total		**5**		**57**	**100**

Plate 6.1: Scale Slag

Plate 6.2: Cake Slag

Plate 6.3: Spear Slag

6.3.1.5 Thermal Condition

Table 6.7 below shows thermal conditions of smithing slag from Nundu arranged according to quantity and percentage. Out of smithing slag collected, 38 slag pieces are melted slag (M) amounting to 67 percent and 19 are conglomeration slag (C) amounting to 33 percent.

Table 6.7: Thermal Conditions of Nundu Slag

S/No.	Thermal Conditions	Symbol	Frequency	Percent
1	Melted	M	38	67
2	Conglomeration	C	19	33
Total		**2**	**57**	**100**

6.3.1.6 Luster

The analysis of luster attribute shows that smithing slag has a metallic luster (M) by 100 percent. This indicates that all the analyzed slag pieces are metallic.

6.3.1.7 Porosity

Table 6.8 shows porosity property of Nundu slag. Out the smithing slag examined, 49 slag pieces equivalent to 86 percent are very low porous (VL), 7 pieces of slag equivalent to 15 percent are not porous (N), and one piece equivalent to 2 percent are low porous (L).

Table 6.8: Porosity of Nundu Slag

S/No.	Rate of Porosity	Symbol	Frequency	Percent
1	Very Low	VL	49	86
2	Nil	N	7	12
3	Low	L	1	2
Total		**3**	**57**	**100**

6.3.1.8 Magnetism

Table 6.9 presents ferromagnetic property of smithing slag according to which, 54 percent equivalent to 31 slag pieces show high magnetism (H), 28 percent equivalent to 16 slag pieces show medium magnetism (M), 16 percent equivalent to 9 slag pieces show low magnetism (L) and 2 percent equivalent to 1 slag piece shows no magnetism (N).

Table 6.9: Magnetism of Nundu Slag

S/No.	Rate of Magnetism	Symbol	Frequency	Percent
1	High	H	31	54
2	Medium	M	16	28

3	Low	L	9	16
4	Nil	N	1	2
Total		**4**	**57**	**100**

6.3.1.9 Color

Table 6.10 shows 16 combinations of colors for smithing slag from Msete site. The combinations are put in order of their frequency and percentage: 13 slag pieces are brownish gray (BG) amounting to 23 percent, 11 slag pieces are reddish brown (RB) amounting to 19 percent, 6 slag pieces are light gray (LG) amounting to 11 percent, 5 slag pieces are dark brown (RB) amounting to 9 percent, 4 slag pieces are yellowish brown (YB) and yellowish red (YR) all amounting to 7 percent, 3 slag pieces are dark gray (DG) amounting to 5 percent, 2 slag pieces are reddish gray (RG) and reddish yellow (RY) all amounting to 3 percent, and one piece is dark red (DR), light brown (LB), red, whitish brown (WB), brown yellow (BY), yellowish gray (YG), and brownish red (BR) all amounting to 2 percent.

Table 6.10: Colors of Nundu Slag

S/No.	Type of Color	Symbol	Frequency	Percent
1	Brownish Gray	BG	13	23
2	Reddish Brown	RB	11	19
3	Light Gray	LG	6	11
4	Dark Brown	DB	5	9
5	Yellowish Brown	YB	4	7
6	Yellowish Red	YR	4	7
7	Dark Gray	DG	3	5
8	Reddish Gray	RG	2	3
9	Reddish Yellow	RY	2	3
10	Dark Red	DR	1	2
11	Light Brown	LB	1	2
12	Red	R	1	2
13	Whitish Brown	WB	1	2
14	Brownish Yellow	BY	1	2

15	Yellowish Gray	YG	1	2
16	Brownish Red	BR	1	2
17		**16**	**57**	**100**

6.3.1.10 Inclusions

Table 6.11 shows inclusions of smithing slag from Nundu site. Out of the collected slag, 41 slag pieces (72%) are free from inclusions (N), 12 slag pieces (21%) have sand inclusions (SA), 3 pieces (5%) have charcoal inclusions (CH) and 1 slag piece (2%) has tuyere inclusions (TU).

Table 6.11: Inclusions of Nundu Slag

S/No.	Inclusion Materials	Symbol	Frequency	Percent
1	Nil	N	41	72
2	Sand	SA	12	21
3	Charcoal	CH	3	5
4	Tuyere	TU	1	2
Total		**4**	**57**	**100**

6.3.1.11 Impressions

Table 6.12 shows kinds of impressions found in smithing slag from Nundu site. While 35 slag pieces equivalent to 61 percent show no clear impressions (M/), 17 slag pieces equivalent to 30 percent show no impressions (N). Also, 4 slag pieces equivalent to 7 percent show ground floor impressions (GR) and a piece shows wood (WO) impressions.

Table 6.12: Impressions of Nundu Slag

S/No.	Impression Materials	Symbol	Frequency	Percent
1	Not Identified	M/	35	61
2	None	N	17	30
3	Ground Floor	GR	4	7

4	Wood	WO	1	2
Total		**4**	**57**	**100**

6.3.1.12 Fragmentation or Breakage

Table 6.13 shows the breakage patterns of Nundu slag. Out the collected slag, eleven slag pieces (19%) are broken are broken one side (1) and four sides (4), 10 slag pieces (18%) are broken two sides (2) and three sides (3), 9 slag pieces (16%) are not broken (0) and 6 slag pieces (11%) are broken five sides (5).

Table 6.13: Fragmentations of Nundu Slag

S/No.	Rate of Fragmentation	Symbol	Frequency	Percent
1	One Side Broken	1	11	19
2	Four Sides Broken	4	11	19
3	Two Sides Broken	2	10	18
4	Three Sides Broken	3	10	18
5	Not Broken	0	9	16
6	Five Sides Broken	5	6	11
Total		**6**	**57**	**100**

6.3.1.13 Weathering

This property includes oxidation and rusting of smithing slag. Table 6.14 presents the levels of weathering processes on smithing slag from Nundu. Twenty pieces of slag which is equivalent to 35 percent are affected four sides (4). While 16 pieces of slag which is equivalent to 28 percent are affected five sides (5), 15 pieces of slag which is equivalent to 26 percent are affected three sides (3). Also, 4 pieces of slag which is equivalent to 7 percent are affected two sides (2) while 2 pieces of slag which is equivalent to 4 percent are affected six sides (6).

Table 6.14: Weathering of Nundu Slag

S/No.	Rate of Weathering	Symbol	Frequency	Percent
1	Four Sides Oxidized	4	20	35
2	Five Sides Oxidized	5	16	28
3	Three Sides Oxidized	3	15	26
4	Two Sides Oxidized	2	4	7
5	All Sides Oxidized	6	2	4
Total		**5**	**57**	**100**

6.3.1.14 Raw material

The analysis of raw material attribute of smithing slag from Nundu shows that 87 slag pieces are made up of a mixture (M) of raw material, which is equivalent to 100 percent.

6.3.1.15 Surface Condition

Table 6.15 presents types of surface conditions of smithing slag from Nundu site. The data show that 22 pieces of slag equivalent to 39 percent have rough surface (R), 20 pieces of slag equivalent to 35 percent have smooth surface (S), 8 pieces of slag equivalent to 14 percent have somehow smooth surface (SS), 7 pieces of slag equivalent to 9 percent have somehow rough (SR).

Table 6.15: Surface Conditions of Nundu Slag

S/No.	Surface Condition	Symbol	Frequency	Percent
1	Rough	R	22	39
2	Smooth	S	20	35
3	Somehow Smooth	SS	8	14
4	Somehow Rough	SR	7	12
Total		**4**	**57**	**100**

6.3.2 Presentation and Analysis of Slag from Mpembani Site

6.3.2.1 Volume

The volume of smithing slag from Mpembani has a median of 0.43 cc, mean of 13.15 cc and a standard deviation of 41.33 cc. Based on these statistics, Table 6.16 shows that 52 slag pieces are below the median class, 36 are in the median class and 18 are above the median class. The first class is equivalent to 49 percent, the second is equivalent to 34 percent and the third class is equivalent to 17 percent of the total smithing slag. While the minimum value for volume is 0.001 cc, the maximum value for Mpembani slag is 326.80 cc.

Table 6.16: Volume Classes of Mpembani Slag, Quantity and Percent

Class	Class Interval (in cc)	Quantity	percent
Below Median	0-0.42	52	49
Median	0.43-13.15	36	34
Above Median	13.16-326.80	18	17
Total		**106**	**100**

6.3.2.2 Mass

The mass for smithing slag from Mpembani has a median of 4.60 g, mean of 28.62 g and a standard deviation of 66.04 g. Based on these statistics, Table 6.17 shows that 65 slag pieces are below the median class, 18 are in the median class and 23 are above the median class. The first class is equivalent to 61 percent, the second is equivalent to 17 percent and the third class is equivalent to 22 percent of the total smithing slag. While the minimum mass is 0.10 g, the maximum mass is 462.50 g.

Table 6.17: Mass Classes of Mpembani Slag, Quantity and Percent

Class	Class Interval (in cc)	Quantity	Percent
Below Median	0-4.59	65	61
Median	4.60-28.62	18	17
Above Median	28.63-462.50	23	22
Total		**106**	**100**

6.3.2.3 Density

Smithing slag from Mpembani site has a median of 7.53 g/cc, mean of 369.21 g/cc and a standard deviation of 1132.14 g/cc. Based on these statistics, the entire range for density of slag is divided into three classes, namely below the median, median and above median. Table 6.18 shows that 53 slag pieces are below the median class; 37 are in the median class and 16 slag pieces are above the median class. The quantity for the first class is equivalent to 50 percent. While the second is equivalent to 35 percent, the last is equivalent to 15 percent. The minimum value for density of slag from Mpembani is 0.50 g/cc while the maximum value is 164.58 g/cc (See Appendix 2).

Table 6.18: Mass Classes of Smithing Slag, Quantity and Percent

Class	Class Interval (in cc)	Quantity	Percent
Below median	0-7.52	53	50
Median	7.53-369.21	37	35
Above Median	369.22-7421.15	16	15
Total		**106**	**100**

6.3.2.4 Morphology

Table 6.19 presents 6 morphological aspects of slag from Mpembani site in terms of quantity and percent. From the total amount of slag collected, 46 slag pieces are scale-like (SC) (see Plate 6.1), 39 pieces of slag are amorphous (A) equivalent to 37 percent, 15 slag pieces are droplet like (D) equivalent to 14 percent, 11 are cake-like (CK) (see Plate 6.2) equivalent to 13 percent, 2 pieces of slag are slag-tuyere (ST) equivalent to 2 percent and one piece is V-shaped (V) equivalent to 1 percent.

Table 6.19: Morphology of Smithing Slag

S/No.	Type of Morphology	Symbol	Plate No.	Frequency	Percent
1	Scale	SC	6.1	46	43
2	Amorphous	A		39	37
3	Droplet	D		15	14
4	Cake	CK	6.2	3	3
5	Slag-Tuyere	ST		2	2
6	V-shaped	V		1	1
Total		**6**		**106**	**100**

6.3.2.5 Thermal Condition

Table 6.20 below shows thermal conditions of smithing slag from Mpembani arranged according to quantity and percentage. Out of smithing slag collected, 67 slag pieces are melted slag (M) amounting to 63 percent, 31 are conglomeration slag (C) amounting to 29 percent and 8 are flow slag (F) amounting to 8 percent.

Table 6.20: Thermal Conditions of Mpembani Slag

S/No.	Thermal Condition	Symbol	Frequency	Percent
1	Melted	M	67	63
2	Conglomeration	C	31	29
3	Flow	F	8	8
Total		**3**	**106**	**100**

6.3.2.6 Luster

The analysis of luster attribute shows that smithing slag has a metallic luster (M) by 100 percent, which indicates that smithing slag is metallic.

6.3.2.7 Porosity

Table 6.21 shows porosity property of smithing slag from Mpembani site. Out the smithing slag examined, 92 slag pieces (86%) have very low porosity (VL), 6 slag pieces (6%) are not porous (N), 7 slag pieces (7%) and one piece(1%) has high porosity.

Table 6.21: Porosity of Mpembani Slag

S/No.	Rate of Porosity	Symbol	Frequency	Percent
1	Very Low	VL	92	86
2	Nil	N	6	6
3	Low	L	7	7
4	High	H	1	1
Total		**4**	**106**	**100**

6.3.2.8 Magnetism

The following Table 6.22 presents ferromagnetic property of smithing slag. Sixty nine slag pieces of collected slag equivalent to 64 percent are highly magnetic (H), 20 pieces equivalent to 19 percent have medium magnetism (M), 15 pieces equivalent to 14 percent have low magnetism (L), and one slag amounting to 1 percent has no magnetism (N) and very low magnetism (VL).

Table 6.22: Magnetism of Mpembani Slag

S/No.	Rate of Magnetism	Symbol	Frequency	Percent
1	High	H	69	64
2	Medium	M	20	19
3	Low	L	15	14
4	Nil	N	1	1
5	Very Low	VL	1	1
Total		**5**	**106**	**100**

6.3.2.9 Color

Table 6.23 shows 23 colors of smithing slag from Mpembani site. The combinations are presented according to quantity and percentage. Out of 106 smithing slag examined, 18 slag pieces have dark gray color (DG) amounting to 17 percent, 15 slag pieces have brownish gray color (BG) amounting to 14 percent, 12 slag pieces have gray color (G) amounting to 11 percent, 10 slag pieces have whitish gray color (WG) and reddish gray (RG) all amounting to 9 percent, 8 slag pieces have reddish brown color (RB) amounting to 7 percent, 7 slag pieces have yellowish brown color (YB) amounting to 7 percent, 6 slag pieces have whitish brown color (WB) amounting to 6 percent, 5 slag pieces have light gray color (LG) amounting to 5 percent, 3 slag pieces have brownish yellow color (BY) amounting to 3 percent, 3 slag pieces have dark brown color (DB) amounting to 3 percent, 2 slag pieces have grayish brown color (GB) and whitish yellow (WY) all amounting to 2 percent, one piece has grayish red (GR), pale yellow (PY), reddish yellow (RY), whitish red (WR) and brownish red color(BR).

Table 6.23: Colors of Mpembani Slag

S/No.	Type of Color	Symbol	Frequency	Percent
1	Dark Gray	DG	18	17
2	Brownish Gray	BG	15	14
3	Gray	G	12	11
4	Whitish Gray	WG	10	9
5	Reddish Gray	RG	10	9
6	Reddish Brown	RB	8	7
7	Yellowish Brown	YB	7	7
8	Whitish Brown	WB	6	6
9	Light Gray	LG	5	5
10	Brownish Yellow	BY	3	3
11	Dark Brown	DB	3	3
12	Grayish Brown	GB	2	2
13	Whitish Yellow	WY	2	2
14	Grayish Red	GR	1	1
15	Pale Yellow	PY	1	1
16	Reddish Yellow	RY	1	1
17	Whitish Red	WR	1	1
18	Brownish Red	BR	1	1
Total		**18**	**106**	**100**

6.3.2.10 Inclusions

Table 6.24 shows inclusions of smithing slag from Mpembani site. Out of the collected slag, 81 slag pieces are free from inclusions (N) which is equivalent to 76 percent, 14 have sand inclusions (SA) which is equivalent to 13 percent, 5 have tuyere inclusions (TU) equivalent to 5 percent, 4 slag have iron inclusions (Fe) (Plate 6.4) amounting to 4 percent and 2 pieces equivalent to 2 percent have charcoal inclusions (CH)

Table 6.24: Inclusions of Mpembani Slag

S/No.	Inclusion Materials	Symbol	Frequency	Percent
1	Nil	N	81	76
2	Sand	SA	14	13
3	Tuyere	TU	5	5
4	Iron Metal	Fe	4	4
5	Charcoal	CH	2	2
Total		**5**	**106**	**100**

Plate 6.4: Smithing Slag Iron Inclusion

6.3.2.11 Impressions

Table 6.25 shows kinds of impressions found in smithing slag from Mpembani site. While 51 slag pieces equivalent to 48 percent show no clear impressions (M/), 43 slag pieces equivalent to 40 percent show no impressions (N). Also, 6 slag pieces equivalent to 6 percent show ground floor (GR) and wood (WO) impressions.

Table 6.25: Impressions of Mpembani Slag

S/No.	Impression Materials	Symbol	Frequency	Percent
1	Not Identified	M/	51	48
2	None	N	43	40
3	Iron Metal	Fe	6	6
4	Ground Floor	GR	6	6
Total		**4**	**106**	**100**

6.3.2.12 Fragmentation or Breakage

Table 6.26 shows the breakage patterns of Mpembani slag. Out the collected slag, 30 slag pieces (28%) are broken three sides (3), 22 slag pieces (21%) are broken two sides (2), 17 pieces (16%) are broken four sides (4), 16 slag pieces (15%) are broken one side (1) and 7 slag pieces (7%) are broken five sides (5).

Table 6.26: Fragmentations of Mpembani Slag

S/No.	Rate of Fragmentation	Symbol	Frequency	Percent
1	Three Sides Broken	3	30	28
2	Two Sides Broken	2	22	21
3	Four Sides Broken	4	17	16
4	One Side Broken	1	16	15
5	Five Sides Broken	5	7	7
Total		**5**	**106**	**100**

6.3.2.13 Weathering

This property includes oxidation and rusting of Mpembani slag. Table 6.27 presents the levels of weathering processes on smithing slag from Mpembani. Twenty nine pieces of slag which is equivalent to 27 percent are affected two sides (2). While 25 pieces of slag which is equivalent to 24 percent are affected one side (1), 21 pieces of slag which is equivalent to 20 percent are affected three sides (3). Also, 15 pieces of slag which is equivalent to 14 percent are affected four sides (4) and 11 pieces equivalent to 10 percent are affected five sides (5). While 3 pieces of slag which is equivalent to 3 percent are not affected (0), 2 slag pieces which is equivalent to 2 percent are affected six sides (6).

Table 6.27: Weathering of Mpembani Slag

S/No.	Rate of Weathering	Symbol	Frequency	Percent
1	Two Sides Oxidized	2	29	27
2	One Side Oxidized	1	25	24
3	Three Sides Oxidized	3	21	20
4	Four Sides Oxidized	4	15	14
5	Five Sides Oxidized	5	11	10
6	Not Oxidized	0	3	3
7	All Sides Oxidized	6	2	2
Total		**7**	**106**	**100**

6.3.2.14 Raw material

The analysis of source material attribute shows that 106 slag pieces from Mpembani site are made up of a mixture (M) of raw material, which is equivalent to 100 percent.

6.3.2.15 Surface Condition

Table 6.28 presents types of surface conditions of smithing slag from Mpembani site. The data show that 49 pieces of slag equivalent to 46 percent have smooth surface (S), 35 pieces of slag equivalent to 33 percent have rough surface (R), 15 pieces of slag equivalent to 14 percent have somehow smooth surface (SS) and 7 pieces of slag equivalent to 7 percent have slippery surfaces (SL).

Table 6.28: Surface Conditions of Mpembani Slag

S/No.	Surface Condition	Symbol	Frequency	Percent
1	Smooth	S	49	46
2	Rough	R	35	33
3	Somehow Smooth	SS	15	14
4	Slippery	SL	7	7
Total		**4**	**106**	**100**

6.4 Summary

This chapter has dealt with slag from Nundu and Mpembani sites. The focus has been on physical attributes. The following table summarizes the findings from the two sites.

Table 6.29: Attribute Analysis from Nundu and Mpembani Sites

		Nundu Slag		Mpembani Slag		Average	
S/No.	**Attribute**	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
1	Volume (cc)	25	2	13.2	0.4	19.1	1.2
2	Mass (g)	203.4	28	29	5	116.2	16.5
3	Density (g/cc)	13	7	369	8	191	7.5
		Mode	**Frequency**	**Mode**	**Frequency**	**Mode**	**Frequency**
4	Morphology	SC	11	SC	46	SC	29
5	Thermal Condition	M	38	M	67	M	53
6	Luster	M	57	M	106	M	82
7	Porosity	VL	49	VL	92	VL	71
8	Magnetism	H	31	H	69	H	50
9	Color	BG	13	DG	18	G	16
10	Inclusion	N	41	N	81	N	61
11	Impressions	M/	35	M/	51	M/	43
12	Fragmentation	1,4	11	3	30	3	21
13	Weathering	4	20	2	29	3	25
14	Source Material	M	57	M	106	M	82
15	Surface Conditions	R	22	S	49	S	36

CHAPTER SEVEN

COMPARATIVE ANALYSIS: SMELTING VS. SMITHING SLAG

7.1 Preamble

This chapter discusses the research findings presented in the last two chapters. The aim is to produce a synthesized explanation of the research problem stated in chapter one. The discussion focuses on comparison between the findings from smelting and smithing sites. It starts with a table (Table 7.1) which summarizes the findings for the purpose of outlining similarities and differences between smelting and smithing slag. It then presents a description of the table. While the sites are lastly revisited to show how the discussed differences of metalliferous slag apply, qualitative data from two sites are interpreted in section 7.5. This chapter gives a way to the conclusion of the research problem.

7.2 Similarities of Smelting and Smithing Slag

The analysis presented in chapters five and six and summarized in Table 7.1 below have shown that smelting and smithing slag is generally similar in attributes such as luster, color, porosity, source materials, inclusion and impressions.

Table 7.1: Summary of Comparative Analysis (Average)

		Smelting Slag		Smithing Slag	
S/No.	**Attribute**	**Mean**	**Median**	**Mean**	**Median**
1	Volume (cc)	454.5	69.25	19.1	1.2
2	Mass (g)	1458	687.5	116.2	16.5
3	Density (g/cc)	149.5	3	191	7.5
		Mode	**Frequency**	**Mode**	**Frequency**

4	Morphology	CK	11	SC	29
5	Thermal Condition	F	96.5	M	53
6	Luster	M	184.5	M	82
7	Porosity	VL	144.5	VL	71
8	Magnetism	L	133	H	50
9	Color	G	42	G	16
10	Inclusion	N	175	N	61
11	Impressions	M/	123	M/	43
12	Fragmentation	2	52	3	21
13	Weathering	1	57.5	3	25
14	Raw Material	M	183.5	M	82
15	Surface Conditions	R	68.5	S	36

The luster for both smelting and smithing slag is metallic. The data show that both are metallic almost a hundred percent, which indicates that both types of slag are purely metallic. The metallic luster is attributed to the use of metallic raw materials such iron ores for smelting slag and the use of bloom that is already metallic for smithing slag. Also, a careful observation and examination of slag in the field showed that surface slag have a more brightening luster than those from excavations on one side. This is attributed to their exposure to the sun and other agents such as rains, and they are free from many acidic chemical reactions that take place in the soils. On the other side, surface modern smithing slag have a more brightening luster than surface ancient smithing slag, which is attributed to time dimension.

The analysis summarized in Table 7.1 above indicates that smelting and smithing slag has mixture source materials almost a hundred percent and made up of tuyeres by one (1) percent. This suggests that the source materials for smelting and smithing slag are significantly mixture. They are mixture of source materials because of the nature of the raw materials such as ores, fluxes, and furnace walls that were put into the furnace for smelting process. This also shows that in the field it is easy to identify source material for smelting and smithing slag as mixture or not. This further implies that if different materials are used, it is straight for one to identify source materials for metalliferous slag. While one percent of raw materials are tuyeres in/on slag, this is not a significant explanation. Therefore, smelting and smithing slag share common source materials attribute.

While brownish gray (BG) and dark gray (DG) are significant color combinations for smelting and smithing slag respectively, Table 7.1 presents that smelting and smithing slag share gray as a chief color. Other colors shared by both types are brown, red, and yellow (see Chapters Five and Six). Therefore, in the field one expects to find both slag types with these colors. Colors that are not shared are discussed in section 7.3 this chapter.

While Table 7.1 shows smelting and smithing slag has very low porosity, it is presented more specifically that smithing slag is less porous than smelting slag (see Chapters Five and Six). While over 99 percent smelting slag are porous, smithing slag are porous bodies by 92 percent. The rates of porosity for smelting include: nil, very low, low and medium. Porosity rates for smithing slag ranges from nil to high. While it is in record that smelting slag is more porous compared to smithing slag, it is equally important however to note that quantitatively smelting and smithing slag are porous bodies than being non porous bodies.

Table 7.1 shows that smelting and smithing slag is generally free of inclusions, which make both types similar. The data presented in Tables 5.24 and 6.24 indicate more specifically that while smelting slag is free from inclusions by 95 percent, smithing slag is free from inclusions by 75 percent, which means smelting slag is freer of inclusions than smithing slag. Observation from smelting site has shown that melted slag have more inclusions than flow ones. While inclusions for smelting slag are sand, tuyere, charcoal, wood and stone, inclusions for smithing slag include: sand, tuyere, iron, and charcoal. Also, the tables clearly shows that while wood and stone inclusions are distinctive for smelting slag, iron tool (Plate 6.4) is for smithing slag. This, among other factors, is attributed to technological factors.

7.3 Differences of Smelting and Smithing Slag

The maximum volume of smelting slag is more than 100 times more than the maximum volume of smithing slag because while the maximum volume for smelting slag is 36000 cc, smithing slag has a maximum volume of 340 cc (see Chapters Five and Six). This means smelting slag is generally bigger than smithing slag because the volume for smelting is 454.5 cc while the mean volume for smithing slag is 19.1 cc. The difference is the result of the large size of smelting slag pieces in terms of length, width and thickness. Also, the standard deviation volume for smelting slag is 280 while that for smithing slag is 51. This is because the sizes for the smelting slag are greatly variable compared to sizes of smithing slag.

While the maximum mass for smelting slag is 26000 grams, smithing slag has a maximum mass of 2400 grams. This shows that the maximum mass for smelting slag is more than 10 times than smithing slag. Also, table 7.1 shows that the mean mass for smelting slag is 1458 grams while the mean mass for smithing slag is 166.2 grams. This means that smelting slag is heavier than smithing slag because of the differences in function and technology of the processes.

The analysis of slag summarized in Table 7.1 indicates that smelting slag is denser than smithing slag. This is due to the fact that the ratio of mass and volume is bigger for smelting slag than for smithing slag. For example, data show that smelting slag has a maximum density of 38000 g/cc, which is four times more than smithing slag with maximum density of 8000 g/cc (see Chapters Five and Six). Also, while smelting slag is more frequent between 0 and 2.98 g/cc, smithing slag is more frequent between 0 and 7.47 g/cc. This is equivalent to 50 percent and 48 percent respectively. While the standard deviation density for smelting slag is 1949, that for smithing slag is 936. This is because the sizes for the smelting slag are greatly variable compared to smithing slag sizes.

While there are more morphological classes in smelting slag than in smithing slag (Tables 5.6 and 6.6), Table 7.1 presents that at average cake like and scale like shapes are significant for smelting and smithing slag respectively. although amorphous slag is the most frequent it is left out for comparison because it is common for each type of slag and it is the results of common factors such breakage and thermal conditions, hence making it not a good criterion for distinguishing smelting from smithing slag. While amorphous, cake-like, droplet and pyramidal are significant shapes for smelting slag, amorphous, scale, and droplet are significant shapes for smithing slag. In addition, while smelting slag contains numerical shapes such as 4-shaped, smithing slag does not. This, among other factors, is attributed to the nature, function and technology of smelting process.

Smelting slag went through more thermal conditions than smithing slag. For example, it is shown in Tables 5.7 and 6.7 that while smelting slag underwent four main thermal conditions namely flowing slag temperature, melted (rough and smooth) slag temperature, partially reduced slag temperature and non reduced slag room temperature, smithing slag was affected by two thermal conditions: melted (rough and smooth) slag temperature and flow slag temperature. In addition, there are no non reduced or partially reduced slag temperatures in smithing process because slag from smithing was already reduced through smelting. Also, most of the slag in smelting site flowed and less melted and most of the slag in smithing slag melted and very few flowed. At average, smelting slag has flow thermal condition while smithing slag has melted thermal condition (Table

7.1). This is because high temperature was reached during reduction for technological function than during forging process.

Smithing slag is more magnetic than smelting slag. Table 7.1 presents that, while at average smelting slag has low magnetism, smithing slag has high magnetism. Smithing slag pieces have more high magnetism than smithing by 40 percent (Tables 5.22 and 6.22). It was observed from the field that smelting slag pieces with high magnetism are cake like because the bloom collected there. Moreover, the differences in magnetism rates between the two slag types are attributed to the nature of the smelting and smithing processes, which is different in terms of technology and function. From the data, it is correct to suggest that smelting and smithing slag are mostly magnetic bodies and it was difficult for ancient technicians to separate 100 percent pure iron from slag.

While colors for smelting and smithing slag are generally grayish, they also vary as follows. Tables 5.23 and 6.23 present that orange and olive colors are distinctive for smelting slag while white color is specifically for smithing slag. Generally, it is recognized that colors are, among other factors, the functions of raw materials and thermal conditions.

Table 7.1 shows that generally smelting and smithing slag has no clear impressions. This is because the data in the Tables 5.25 and 6.25 show that while 67 percent of smelting slag has no clear impressions, only 53 percent of smithing slag has no clear impressions.

This suggests that while it is possible to recognize impressions on slag, it is not easy sometimes to identify specific impression materials of slag in the field. Also, smelting slag more specifically has more impressions than smithing slag, with 81% by 63% respectively (see Chapters Five and Six). This is further strengthened by the fact that while smelting slag is not impressed by 18 percent, smithing slag is not impressed by 37 percent. While the former has impressions of ground floor; flow marks, wood and stones, ground floor, iron and wood impress the latter. As presented in the Tables, tuyere is a distinctive impressing material for smelting slag.

Smelting slag is more fragmented than smithing slag. It is presented in Table 7.1 that smelting slag are not broken any side or dimension by ten percent while smithing slag are not broken any side by fourteen percent. In addition, while there are slag pieces broken all sides in smelting sites, there are no slag pieces in smithing site that are broken all sides (see Chapters Five and Six). This, among other factors, is the function of the size of slag type.

Table 7.1 shows that smelting slag is less weathered compared to smithing slag. For example, while 20 percent of smelting slag is not weathered, only 2 percent of smithing slag is not weathered (see Tables 5.27 and 6.27). Also, only a low amount of smelting slag (2 percent) is affected by weathering between five and six sides compared to smithing slag which is 19 percent. The fact that smelting slag is less weathered indicates that smelting slag is resistant to weathering processes, which is attributed to low amount of iron left in the slag because oxidation and rusting are the function of iron combined with moisture. Smithing slag is more affected by weathering factors because of their exposure to direct sun and high content of iron in the slag.

The data presented in Chapters Five and Six as summarized in Table 7.1 show that smelting slag is rougher than smithing slag. Analysis table (Appendix 2) shows that most rough smelting slag is melted and partially reduced ones while flow slag is either smooth or slippery. On the other side, smithing slag is smoother than being rough and slippery. Most smooth and slippery smithing slag is either scale or droplet while rough smithing slag is basically conglomerated ones. All these suggest that smelting slag are more rougher than smithing slag, that smithing slag are more smoother than smelting slag, and that smelting slag are more slippery than smithing slag.

7.4 Intra and Inter Sites Analysis

This section discusses differences within smelting and smithing sites in terms of comparative analysis. It starts by differences within smelting sites followed with the differences within smithing sites. The last part compares smelting and smithing sites in terms of their differences.

The study shows that smelting sites look different based on the following aspects. First, Ngongwa furnaces were dug in the ground as bowl furnaces. Msete furnaces were superstructures. The cake slag from Ngongwa is bigger and heavier than Msete's cake slag. The difference is attributed to their breakage conditions. For instance, those at Ngongwa were still intact which was not the case at Msete as the cake slag was broken into pieces. Also, the cake slag at Ngongwa was less magnetic compared with Msete slag. I think this is due to the fact that the smelting technology at the two sites was different. We see more flow slag and less melted slag at Msete than at Ngongwa (see Chapter Five); Ngongwa tuyeres were shorter and more flared than Msete tuyeres; and more efficient utilization of ores at Msete as there were no ores (or not reduced at all slag) than at Ngongwa where some not reduced slag was found.

The data suggest for differences and similarities between smithing sites. Mpembani site is different from Nundu and Tumbe sites in that it is a modern smithing site. It is a site with very low percent of droplet slag than the two. This is due to the nature of raw materials used, that is, already processed metal(s) or scrap iron are almost pure. In addition, while the scale slag is present in large quantity, it is smaller and lighter than the two sites. Tumbe site has a lot of droplets slag (Mapunda 2006). This has been attributed to processing of bloom rather than ready made iron (Mapunda 2006). This case has been found at Nundu site where a lot of droplets slag coupled with conglomeration slag were recovered. That is to say Nundu site was processing iron blooms. The high frequency of conglomeration slag at Nundu strengthens this. At the same time, the big size of conglomeration slag at Nundu site can be used to suggest that refining of the bloom was not separately performed at Nundu, which is similar to the case of Maa-speaking of North-central Kenya (Larick 1986). This can be attributed to the nature of the ores used especially those bearing high percent of iron. This is, at the site, supported by highly magnetic cake slag. Thus, unless a refining site is found near or around Nundu or Msete, it is inferred that iron smelted at Msete was not refined. It is important to note that smithing slag from all the sites share significant physical properties such as morphology, magnetism and mass.

The intra site analysis shows that smelting sites are different from smithing sites in that, while smelting sites bear evidences such as blocky slag, furnaces and furnace walls, slagy tuyeres as characteristic materials, smithing sites bear scale, droplet and conglomeration in large quantity. Also, smithing slag in the field has high magnetism coupled with iron metal inclusions of slag.

7.5 Qualitative Data Analysis

Interviews and Focus Group Discussions attributed the location of Ngongwa smelting site to the availability of raw materials such as water and ore and charcoal. Ore was obtained at a distance of between two and three kilometers from the site. The ores were quarried or collected from the surface. Water was collected from the nearby valley one and a half kilometers; and wood or charcoal could be collected from around the hill. All these factors make Ngongwa an industrial site big as it is today as revealed through the abundance of slag, furnace walls, and tuyeres. I visited the source area of water to confirm and I found a valley that was by then without water because of dry season.

Data from the Mpembani interviews show that the technology here was inherited. It was reported that three related generations have dealt with the technology at the site. The smith use scrap iron collected from within and outside Northern Pemba. Some scraps have low iron content and so produce lots of conglomeration slag while scraps rich in iron produce little conglomeration slag. it was observed that normally the forge requires a minimum of three people to operate: one for bellowing, one for holding the hot metal and the last for hammering (see Figure 4.6). They also said that there are two main smithing seasons namely before farming activities in December to April and after harvesting, that is between July and September. Types of tools produced include nails for boat construction and plough fixing, knives, needles, axes, and coconut scratchers. Through observations, this technology is very exciting. The technology gives the smiths recognition and money at different scales. All this help us to learn what was there in the past.

7.6 Summary

This chapter has discussed the physical properties of smelting and smithing metalliferous slag in terms of similarities and differences. It has also discussed the implication of the properties to smelting and smithing sites. The following chapter draws a conclusion from this chapter in relation to the research problem.

CHAPTER EIGHT

CONCLUSIONS AND SUGGESTIONS

8.1 Preamble

This chapter provides conclusions about the research problem and objectives. The aim is to show in summary form how smelting slag relates to smithing slag in terms of physical properties on one hand, and how the former differs from the latter on the other. It ends by providing some suggestions for future researchers for enhancing better understanding of physical properties of metalliferous slag.

8.2 The Conclusion

Smelting and smithing slag generally share three physical properties. These are luster, porosity, some colors, inclusion, impressions and source materials. Therefore, in this manner they are similar. This study, however, has found out that they differ in many other physical properties. Smelting slag is bigger, heavier, denser and rougher than smithing slag. While smelting slag has flow thermal condition and cake like morphology, smithing slag has melted thermal condition and scale like morphology. Lastly, smelting slag is less magnetic; less weathered, and more fragmented than smithing slag. It is important to note more specifically that smelting slag is more porous and more impressed than smithing slag.

It has been found out that both bowl furnaces and superstructure furnaces were used in smelting in Iringa Region. Also, it is true that not all smelted bloom was refined there. Smelting and smithing sites are different in terms of characteristic features such as types of slag, tuyeres, and furnaces or hearths.

8.3 Suggestions

This work is confined to smelting and smithing metalliferous slag; it has not dealt with refinery slag. There is a need in the future to include refining slag so as to determine their unique physical properties that can be used to distinguish them from smelting and smithing slag. This will make slag identification more comprehensive.

While in the laboratory, this work lacked a streak plate and Moh's scale for streak and hardness attributes analysis, in the field it dealt with surface smithing slag from Nundu because of the lack of enough funds for excavations. In future there is a need to consider these two aspects for a comprehensive explanation of the properties of metalliferous slag.

Lastly, I have examined the properties of metalliferous slag through physical analysis leaving out chemical and metallographic analyses. For future researches, it is important to incorporate elemental and phase analyses for a more comprehensive comparative guide.

8.4 Summary

This chapter basically has outlined the main conclusions of this work in terms of smelting and smithing slag distinguishing criteria. It has provided problems encountered in the study and has suggested future archaeometallurgical research areas.

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APPENDICES

Appendix 1: Legend for Physical Analysis of Metalliferous Slag

1. **Site**
   This is the name of the being investigated archaeological site e.g. Ngongwa
2. **Analysis Number**
   This is a laboratory or field identity number given serially to a specimen or a group of specimens with common properties of a given site. **Note**: Every site will have its own analysis numbers controlled.
3. **Bag Number**
   This is the number given to bagged specimens during analysis.
4. **Length (in cm)**
   This is the distance of the longest straight line across the sample, not necessarily a diameter or longest edge. In case of compound samples take the length of the largest sample. **Note**: (1) measurements may be in mm and (2) alternatively,
   S (Short) length slag ranges between 0 and 8 centimeters,
   M (Medium) length slag ranges between 8 and 20 cm,
   L (Long) length slag ranges between 20 and 32 cm, and
   VL (Very Long) length slag ranges between 32 and 50 cm.
5. **Width (in cm)**
   This is a quantitative attribute obtained by measuring the longest distance at 90 degrees (or perpendicular) to the length axis using a callipers. **Note:** alternatively,
   S (Short) width slag ranges between 0 and 6 centimeters,
   M (Medium) width slag ranges between 6 and 16 cm, and
   L (Long) width slag ranges between 16 and 40 cm.
6. **Thickness (in cm)**
   This is a quantitative attribute obtained by measuring the longest distance between two parallel planes of the object or specimen using a callipers. **Note:** alternatively,
   S (Small) thickness slag ranges between 0 and 6 centimeters,
   M (Medium) thickness slag ranges between 6 and 12 cm, and
   B (Big) thickness slag ranges between 12 and 22 cm.
7. **Volume (in cc)**
   This is a quantitative attribute obtained by multiplying the length, width and thickness (Volume =Length X Width X Thickness). Note: alternatively,
   L (Low) volume, slag in the Below Median class,
   M (Medium) volume, slag in the Median class, and
   H (High) volume, slag in the Above Median class.
8. **Mass (in grams)**

This is a quantitative attribute obtained by using a scale. **Note**: for the case of compound samples or measurements a total or compound mass is given.
For qualitative analysis:
L (Low) mass, slag in the Below Median class,
M (Medium) mass, slag in the Median class,
H (Heavy) mass, slag in the Above Median class

9. Density (in g/cc)
This is a quantitative attribute obtained by dividing mass with volume (Density =Mass/Volume). Note: for qualitative analysis or alternatively:
L (Low) density, slag in the Below Median class,
M (Medium) density, slag in the Median class, and
H (High) density, slag in the Above Median class

10. Morphology/Shape = the following symbols to be used
A Amorphous
B Bar
CK Cake like
D Droplet
E Dome
F Flat
H Hemisphere
BA Blocky -- amorphous
AC Acicular
M Molded
N Nugget
O Oval
P Pyramidal
R Blocky –quadrilateral
SP Spherical
SE Spear
HE Heart-shaped
C Cylindrical
BCK Blocky-cake like slag
L L-shaped slag
ST Slag-tuyere slag
BE Bean-shaped slag
SS Short sticks like slag
R Radial slag
Y Y-shaped slag
FN Fingers like slag
FL Flow slag
S S-shaped slag
4 4-shaped slag
8 8-shaped slag
AN Animal like slag

CS Curved sticks like slag
K K-shaped slag
BP Blocky-pyramidal slag
T T-shaped slag
TR Triangle shape slag
TS Tuyere Slag
Y Y-shaped slag
FS Fish like slag
X X-shaped slag
DE Dendritic like slag
V V-shaped slag

11. Thermal Conditions

C Conglomeration- no flow marks, rough surface
B Baked
F Flow, slag showing flow marks
M Melted materials –no flow marks, smooth surface (common slag)
P Pumice-like
R Reduced partially
V Vitrified ceramic

12. Luster

C Ceramic
G Glass
M Metallic
Y Greasy

13. Porosity

This is a descriptive attribute on the ability and extent of a slag to allow water or any liquid passage. Each slag is judged in relation to others.
N Nil (Slag can not allow any liquid to pass through)
VL Very Low (Slag shows holes not necessary able to pass liquid through)
L Low (Slag can allow very little liquid to pass through)
M Medium (Slag can allow little liquid to pass through)
H High (Slag can allow any liquid to freely pass through)

14. Magnetism

This attribute looks for the ability of a slag to attract a magnet (ferromagnetic property). **Note:** a magnetic compass can be used to determine slag magnetism. That when the specimen is held close to the compass, the north arrow moves (or repels) from the specimen when the sample specimen is magnetic, and it does not repel the specimen if the sample specimen is not magnetic. The extent of repulsion depends on the amount of iron present in the specimen. For the case of a magnet the following are considered:
N Nil (Slag (or its particle(s)) does not attract the magnet at all)
VL Very Low (Only detached particle(s) are attracted to the magnet)
L Low (Slag does very little to attract a magnet)

M Medium (Slag attracts the magnet or significant force of attraction between the two exists, and

HHigh (Slag attaches itself to the magnet because of the forces between them.

15. Color

This attribute shows a color of a specimen as observed from its surfaces. Note: in case of two colors featuring the specimen, the first color occupies more the specimen than the second color. For example, Brownish Gray = more brown than gray. Light or dark shows the extent of the dealt color. E.g. Light gray or light green = simple or not dark color. Metalliferous slag have the following colors: **BG** (Brownish Gray), **RB** (Reddish Brown), **GB** (Grayish Brown), **DG** (Dark Gray), **RG** (Reddish Gray), (**G**) Gray, **LG** (Light gray), YB (Yellow Brown), **WG** (Whitish Gray), **DB** (Dark Brown), **WB** (Whitish Brown), **BY** (Brownish Yellow), **YR** (Yellowish Red), **RY** (Reddish Yellow), **WY** (Whitish Yellow), **BR** (Brownish Red), **YG** (Yellowish Gray), **WR** (Whitish Red), **PY** (Pale Yellow, **R** (Red), **LB** (Light Brown), **GR** (Grayish Red), **DR** (Dark Red), **DRB** (dark Reddish Brown), **OG** (Orange Gray), **B** (Brown), **LBG** (Light Brownish Gray), **LRG** (Light Reddish Gray), **ORG** (Olive Reddish Gray), and **VDG** (Very Dark Gray).

16. Streak

This is a color of an entire powdered specimen using a streak plate. Colors for streak include the following:

B (Brown), **GR** (Green), **G** (Gray), **BL** (Black), **OR** (Orange), **R** (Red), **Y** (Yellow), and **W** (White).

17. Inclusions

This attribute determines what is included with the specimen.

Slag inclusions aspects include the following:

N (Nil or free of inclusions)

SA sand inclusions

TU tuyeres inclusions

CH charcoal inclusions

WOwood inclusions

ST stone inclusions

Fe iron metal inclusions

18. Impressions

This attribute helps to determine the impressions on a sample or specimen.

Slag impressions aspects include the following:

NSpecimen without any impressions

M/ Specimen with non identifiable impressing materials such as wood, charcoal, etc

Z/ Fussed

Fe Iron Metal Impressions

CCharcoal

ELime

FL Flow marks

G Grass
N None
O Ore
GR Ground floor impressions
S Gas
TU Tuyere
WO Wood Impressions
X Slag
Y Clay
ST Stone Impressions

19. Fragmentation

This attribute looks at the rate of fragmentation or breakage of a slag.
0, 1, 2, 3, 4, 5 and 6 symbolize the range of fragmentation:
0 not broken at all
1 broken in one edge
2 broken in two edges
3 broken in three edges
4 broken in four sides
5 broken in five sides
6 broken in all sides
C Cracked

20. Weathering

This attribute looks for the range of oxidization rates of a specimen, which ranges as put here below:
0 Nil (for a non-oxidized specimen)
1 Surface oxidation or one side only
2 Surface oxidation on two sides or one dimension
3 Medium surface oxidation on 3 sides
4 Medium surface oxidation on 4 sides or two dimensions
5 Heavy surface oxidation on 5 sides
6 Deep oxidation all over the sample or three dimensions.
B Blackened by bush fire

21. Raw Materials

This attribute shows the source material for a specimen, which include the following:
C Ceramic – general
O Ore
F Furnace
G Gangue
L Metal
M Mixture —'real slag'
R Rock
S Ground soil
TU Tuyere

22. Surface condition

This attribute looks on the nature of the surface of the specimen, which belong to either of the following aspects:

G Granular
SS Somehow smooth surface
S Smooth surface
SL Slippery smooth surface
SR Somehow rough surface
R Rough surface

23. Rust

This looks of iron rusting on a specimen at three dimensions (3D). Rusting is the result of air moisture and iron combined.

N Nil (Slag is not rusted at all)
VL Very Low (Slag is rusted only one side)
LR Low Rust (Slag is rusted only two sides or one 1D)
R Rust or Medium (Slag is rusted 1.5D or three sides)
HR High Rust (Slag is rusted at least 1.5D or three sides)

24. Quantity

This shows the number of specimen being analyzed. It is particularly important for compound samples as it shows the number of samples that share all physical attributes. Note: A whole number, e.g., 2, 3, 10, etc. indicates that the samples share common features but there is no obvious indication that they originally came from one piece; whereas fractions, e.g., 3/1 indicates that there are three broken pieces that belong to one parent specimen.

Appendix 2: Attribute Analysis of Slag

Appendix 2a: Attribute (Physical) Analysis of Smelting Slag from Ngongwa Site

Analysis No.	Bag. No.	Length (cm)	Width (cm)	Thickness (cm)	Volume (cc)	Mass (g)	Density (g/cc)	Morphology	Thermal	Luster	Porosity	Magnetism	Color	Inclusions	Impressions	Fragmentation	Weathering	Raw Material	Surface Condition	Quantity
1		4.43	3.7	2.13	34.7241	34.5	0.99	A	F	M	VL	N	DB	N	M/	1	0	M	S	1
2		3.38	2.7	1.72	15.5804	11.7	0.75	A	F	M	VL	N	GB	N	M/	4	0	M	S	1
3		3.86	3.4	1.66	21.914	25.9	1.18	FL	F	M	L	N	GB	N	N	2	0	M	SS	1
4		2.94	2.1	1.53	9.4912	11.4	1.20	A	F	M	VL	L	B	N	M/	2	1	M	S	1
5		4.16	1.4	1.97	11.1455	21.45	1.92	H	F	M	VL	N	G	N	N	2	0	M	SS	1
6		3.16	2.6	1.29	10.3948	8.9	0.86	A	R	M	L	N	G	N	N	4	1	M	R	1
7		3.37	2.8	1.14	10.7955	15.3	1.42	D	F	M	VL	N	DG	N	M/	6	0	M	S	1
8		6.13	2.4	1.91	27.7487	37.4	1.35	A	F	M	N	L	DG	N	M/	2	0	M	SS	1
9		5.51	3.2	2.79	49.1933	44.1	0.90	A	R	M	L	L	RG	N	N	3	3	M	R	1
10		3.97	2.3	1.14	10.5904	42.6	4.02	A	F	M	VL	L	DG	N	N	2	0	M	S	5
11		3.71	2.6	9.8	95.6215	15.2	0.16	H	F	M	VL	L	DG	N	M/	0	0	M	S	1
12		7.27	5.6	2.75	111.958	77.1	0.69	A	F	M	VL	L	RG	N	M/	2	1	M	S	1
13		3.93	3.7	1.87	27.3387	71.8	2.63	A	F	M	VL	L	RG	N	M/	2	2	M	SS	1
14		5.29	3.7	2.74	53.1952	106.4	2.00	A	F	M	VL	L	RG	N	M/	3	2	M	S	5
15		4.98	3.5	2.79	49.0465	22.5	0.46	FL	F	M	VL	L	RB	N	M/	6	2	M	S	1
16		2.87	1.7	1.06	5.14132	33.3	6.48	A	F	M	VL	L	RG	N	N	2	1	M	S	4
17		3.29	1.3	9.2	39.0457	13.6	0.35	A	F	M	VL	L	RB	N	N	1	1	M	S	5
18		2.8	1.1	9.4	28.4256	21.3	0.75	A	F	M	VL	M	DB	N	M/	2	0	M	S	6
19		4.25	1.1	1.11	4.95338	17.4	3.51	A	F	M	VL	L	DG	N	M/	2	0	M	S	1
20		5.81	4.8	2.94	82.1615	106.5	1.30	A	F	M	VL	L	RG	N	M/	3	1	M	S	1
21		5.5	4.5	4.08	101.878	82.5	0.81	A	R	M	L	H	RG	N	M/	2	1	M	R	1

22		6.34	4.9	4.88	151.602	145.5	0.96	A	F	M	L	M	RG	N	M/	4	1	M	R	1
23		5.37	3.2	2.75	47.4037	217.1	4.58	A	F	M	VL	L	RG	N	M/	2	3	M	SS	4
24		4.66	2.6	2.14	25.6291	94.5	3.69	A	R	M	L	L	RG	N	N	2	1	M	R	6
25		5.4	3.2	2.89	49.471	148	2.99	A	R	M	L	L	DG	N	N	1	2	M	R	8
26		7.54	4.2	2.54	80.4367	117.7	1.46	A	F	M	VL	L	RG	N	M/	4	1	M	S	1
27		3.57	1.9	1.75	12.1202	57	4.70	A	F	M	VL	L	DG	N	M/	3	0	M	SS	4
28		2.54	1.3	1.24	3.99999	24.7	6.18	A	F	M	VL	L	RG	N	M/	3	1	M	S	6
29		2.32	0.8	0.83	1.59825	26	16.27	C	F	M	VL	N	DG	N	M/	3	0	M	SS	2
30		5.95	4.3	3.37	85.2189	131	1.54	A	F	M	VL	L	DG	N	M/	2	1	M	SS	2
31		5.62	3.8	3.2	68.6989	108	1.57	A	F	M	VL	L	RG	N	M/	2	1	M	SS	1
32		5.96	3.9	2.83	65.2745	134	2.05	A	R	M	L	L	RG	N	M/	2	2	M	R	4
33		6.13	3	3	54.8022	234	4.27	A	F	M	VL	N	DG	N	M/	2	1	M	SS	6
34		3.62	2.8	1.85	19.0195	22.2	1.17	P	R	M	L	N	DB	N	M/	1	0	M	R	1
35		5.53	2.6	1.72	24.8253	42	1.69	M	F	M	VL	N	DG	N	M/	2	0	M	S	1
36		3.01	8.4	0.47	11.8835	6.2	0.52	SS	F	M	VL	L	DB	N	FL	2	4	M	S	2
37		4.78	3.3	1.99	30.9147	71.6	2.32	A	R	M	L	M	RB	N	N	4	0	M	R	4
38		4.25	2.9	2.31	28.4708	122	4.29	A	F	M	VL	L	DG	N	N	2	2	M	S	7
39		4.8	3.3	1.99	31.6171	206.6	6.53	A	M	M	L	L	RG	N	M/	4	0	M	R	12
40		3.15	2.2	1.07	7.34769	94.2	12.82	A	F	M	VL	L	DB	N	N	1	0	M	S	18
41		4.1	2.7	1.71	18.9297	25.6	1.35	A	M	M	L	L	LG	N	N	5	0	M	SS	1
42		4.32	3.8	1.73	28.2502	76.7	2.72	A	M	M	VL	VL	GB	N	N	6	0	M	R	3
43		6.24	2.7	2.23	37.7102	37.8	1.00	A	M	M	VL	N	GB	N	M/	3	0	M	S	1
44		3.69	2.9	2.33	24.8474	65.7	2.64	A	M	M	VL	L	GB	N	N	5	0	M	VR	4
45		4.03	2.4	1.77	16.9768	46.2	2.72	A	F	M	VL	N	DG	N	M/	6	0	M	SS	3
46		5	1.4	0.96	6.672	10.5	1.57	SS	M	M	VL	L	GB	N	N	1	0	M	S	1
47		3	2.5	2.15	16.1895	41.1	2.54	A	M	M	L	L	RG	N	M/	5	3	M	SS	2
48		3.61	3.2	2.31	26.2682	82.8	3.15	A	M	M	VL	L	RG	N	M/	5	1	M	SS	6
49		2.93	1.6	1.18	5.56641	82.5	14.82	A	F	M	VL	L	RG	N	M/	2	1	M	S	8
50		3.97	2.4	9.8	94.5416	125	1.32	A	F	M	VL	L	RB	N	M/	5	2	M	S	12
51		3.28	2	1.25	8.077	221	27.36	A	M	M	VL	L	RG	N	M/	4	3	M	SS	40
52		3.59	2.3	1.88	15.3207	43.5	2.84	A	M	M	VL	L	RB	N	M/	3	4	M	S	7
53		2.73	2	1.16	6.46027	174.5	27.01	A	F	M	VL	L	RG	SA	M/	2	1	M	S	28

54		3.91	3.4	1.86	24.945	162.1	6.50	A	M	M	VL	VL	RG	N	M/	5	1	M	R	18
55		3.38	2.4	1.6	12.817	167.9	13.10	A	F	M	VL	L	GB	N	M/	2	1	M	S	27
56		3.16	1.8	1.48	8.41824	180.8	21.48	A	F	M	VL	M	RG	N	M/	4	1	M	SS	32
57		12.53	12	8.71	1265.98	914.9	0.72	CK	M	M	L	L	DRB	N	N	3	4	M	VR	1
58		9.93	7.1	5.8	407.766	355.6	0.87	A	M	M	L	L	DRB	N	M/	3	4	M	VR	1
59		7.06	6.9	4.26	206.018	211	1.02	A	F	M	VL	L	DRB	N	M/	4	4	M	SS	1
60		7.41	7.3	5.05	271.673	200.4	0.74	A	R	M	VL	L	DRB	N	M/	4	4	M	VR	1
61		7.03	5.7	3.69	147.862	138	0.93	A	F	M	VL	L	DRB	N	M/	3	3	M	R	1
62		12.4	4.9	3.76	226.593	159.9	0.71	C	M	M	VL	L	RB	N	N	4	3	M	VR	1
63		8.04	5.3	4.29	182.805	203	1.11	C	M	M	VL	L	RB	N	M/	3	3	M	SS	1
64		8.52	6.1	3.89	201.177	150	0.75	A	F	M	VL	L	DG	N	M/	3	1	M	R	1
65		7.07	6.3	3.67	162.687	135.2	0.83	A	F	M	VL	L	RG	N	N	3	1	M	SS	1
66		7.06	6.9	4.69	227.806	442.9	1.94	A	M	M	VL	L	RG	N	N	4	4	M	R	3
67		7.17	5.5	4.12	161.586	348.5	2.16	A	F	M	VL	L	RG	N	M/	2	3	M	S	3
68		5.37	2.7	1.24	18.1119	500	27.61	A	F	M	VL	L	RG	N	M/	2	2	M	S	3
69		5.31	4.9	2.25	57.9454	343	5.92	A	F	M	VL	L	RG	N	M/	3	1	M	S	13
70		7.05	5.7	4.77	192.355	177.2	0.92	P	F	M	VL	L	DG	N	M/	0	0	M	R	1
71		6.72	5.1	4.48	153.539	101.6	0.66	A	F	M	VL	L	DG	N	N	3	0	M	R	1
72		4.49	3	2.O6	13.2904	105.6	7.95	A	F	M	VL	L	DG	N	M/	3	0	M	S	4
73		5.62	3.5	2.56	50.7868	184.1	3.62	A	F	M	VL	VL	RB	N	M/	3	1	M	SS	4
74		5.77	4.2	3.91	93.6269	140	1.50	A	F	M	VL	L	DG	N	M/	3	0	M	R	2
75		6.16	3.9	3.93	95.3827	156	1.64	A	M	M	VL	L	RG	N	M/	3	4	M	R	5
76		4.93	3.8	2.96	55.3067	325.5	5.89	A	M	M	VL	L	RB	N	M/	5	2	M	SS	16
77		4	2.1	1.81	14.9868	154.6	10.32	A	F	M	VL	L	DG	N	M/	2	0	M	S	8
78		5.78	2.3	2.19	29.1139	34.6	1.19	H	F	M	VL	L	RB	N	M/	1	2	M	S	1
79		3.18	2.4	1.67	12.7454	24.4	1.91	P	F	M	VL	L	RG	N	M/	3	2	M	S	2
80		4.79	2	1.96	18.4013	184.4	10.02	A	F	M	VL	L	RG	N	M/	2	2	M	S	3
81		4.83	4.1	2.93	57.8813	527	9.10	R	F	M	VL	L	RG	N	M/	3	1	M	S	2
82		2.68	2.2	1.19	7.04813	6.6	0.94	R	F	M	VL	M	RG	N	N	5	4	M	S	1
83		1.16	2.3	1.31	3.47988	122.1	35.09	A	M	M	VL	L	RB	N	M/	4	3	M	SS	16
84		2.47	1.4	1.02	3.55235	34.5	9.71	A	M	M	VL	L	RB	N	M/	2	2	M	S	12
85		3.44	2.1	0.98	7.04581	127.9	18.15	A	M	M	VL	L	BG	N	M/	2	2	M	SS	10

86		2.81	1.8	1.54	7.87587	54.4	6.91	A	F	M	VL	N	BG	N	M/	2	1	M	S	11
87		3.3	1.8	1.14	6.7716	9.3	1.37	H	F	M	VL	L	BG	N	N	4	3	M	S	1
88		3.4	2.8	1.82	17.3883	21.6	1.24	A	F	M	VL	N	RB	N	M/	4	2	M	R	2
89		2.43	1.9	0.95	4.45541	31.6	7.09	A	M	M	VL	L	RG	N	M/	3	3	M	R	12
90		5.07	3.6	2.67	49.0036	837.2	17.08	A	C	M	L	L	RB	N	M/	4	4	M	VR	28
91		10.04	9.7	5.15	501.548	689	1.37	A	F	M	VL	L	RB	N	M/	5	2	M	SS	4
92		10.04	9.7	5.15	501.548	194.1	0.39	P	F	M	VL	L	RB	N	N	5	2	M	SS	3
93		6.74	4.8	3.92	127.612	6400	50.15	A	F	M	L	L	RG	N	M/	4	1	M	SS	287
94		4.01	2.1	2.45	20.7297	420	20.26	A	M	M	VL	L	RB	N	M/	5	2	M	R	134
95		9.51	5.6	2.99	160.088	2800	17.49	A	F	M	VL	L	DG	N	M/	2	0	M	S	112
96		4.94	3.3	3.04	49.8584	1400	28.08	A	M	M	VL	L	RB	N	M/	5	3	M	R	110
97		2.44	2.2	1.33	7.17189	5.3	0.74	TR	C	M	L	H	RB	SA	N	1	3	M	R	1
98		5.22	4.2	2.67	58.2583	650	11.16	A	F	M	VL	L	BG	N	M/	2	1	M	S	36
99		5.91	4.3	3.5	89.1524	700	7.85	A	N	M	VL	L	RG	N	M/	5	1	M	SS	35
100		3.92	3.3	2.45	31.8853	550	17.25	CK	M	M	VL	L	RB	N	M/	6	2	M	R	39
101		7.18	4.5	2.83	90.6245	650	7.17	TR	F	M	VL	L	RG	N	M/	4	3	M	R	38
102		2.1	1.3	0.91	2.50341	1440	575.22	A	M	M	VL	L	RB	N	M/	3	4	M	R	214
103		3.2	2	1.91	12.1629	1400	115.10	A	M	M	VL	L	BG	N	M/	2	2	M	SS	204
104		1.83	1.4	1.04	2.64545	1500	567.01	A	F	M	L	N	DG	N	N	1	0	M	S	210
105		4.17	3.7	2.25	34.5276	1390	40.26	A	M	M	VL	L	BG	N	M/	3	2	M	SS	212
106		4.62	3.1	2.44	35.2839	1540	43.65	A	M	M	VL	L	RB	N	M/	6	3	M	R	216
107		4.36	2.4	1.35	13.891	18.7	1.35	R	F	M	VL	L	LG	N	M/	2	0	M	S	1
108		4.09	2.7	1.83	20.4332	90.9	4.45	A	F	M	VL	L	LRG	N	M/	3	3	M	S	11
109		6.81	14	2.56	244.419	1866	7.63	A	M	M	VL	L	RG	N	M/	3	2	M	SS	392
110		6.16	4.2	2.95	76.8676	1860	24.20	A	M	M	VL	L	DG	N	M/	3	0	M	SS	380
111		3.39	2.3	1.74	13.4488	1966.6	146.23	A	M	M	VL	L	RG	N	M/	3	1	M	R	372
112		3.06	2.1	1.66	10.464	1796	171.64	A	F	M	VL	L	GB	N	M/	4	1	M	S	389
113		2.41	1.5	1.34	4.81181	1890	392.78	A	F	M	VL	N	VDG	N	N	1	0	M	SL	386
114		5.28	2.2	2.08	24.6006	1636	66.50	A	F	M	VL	N	YG	N	N	5	0	M	S	394
115		3.62	2.6	1.98	18.7074	375.9	20.09	A	M	M	VL	N	DG	N	M/	3	0	M	R	22
116		5.89	5.9	5.33	184.595	376	2.04	A	M	M	VL	L	LG	N	M/	5	1	M	VR	22
117		3.81	2.9	2.2	24.224	84.6	3.49	A	R	M	L	M	YR	N	M/	3	5	M	R	8

118		4.13	3.2	1.23	16.2049	3650	225.24	TR	C	M	L	L	RB	N	M/	3	1	M	S	1645
119		0.51	0.4	0.5	0.102	3700	36274.51	D	F	M	VL	H	DG	N	N	1	1	M	SL	1650
120		1.76	1.2	0.83	1.69453	3550	2094.98	A	F	M	VL	L	YG	N	N	1	1	M	SL	1635
121		1.09	0.7	0.6	0.45126	3650	8088.46	H	F	M	VL	N	G	N	N	0	0	M	SL	1646
122		33	26	13	11154	6000	0.54	BCK	M	M	L	M	DRB	N	GR	2	4	M	R	1
123		29	26	6	4524	5800	1.28	BCK	R	M	L	L	RG	N	GR	2	1	M	R	1
124		21	17	11	3811.5	4000	1.05	BCK	M	M	L	L	BG	N	GR	3	1	M	R	1
125		20	14	9.5	2565	1934.1	0.75	BCK	M	M	VL	L	BG	SA	GR	3	2	M	R	1
126		21.5	12	11.5	2967	2240	0.75	BCK	M	M	L	L	RB	N	GR	4	2	M	R	1
127		26.5	23	9	5485.5	3000	0.55	BCK	M	M	L	L	BG	N	GR	3	2	M	R	1
128		25	26	9	5850	5400	0.92	BCK	M	M	L	L	DB	N	GR	2	2	M	R	1
129		47.47	37	20.1	35268.3	25000	0.71	BCK	M	M	VL	L	RB	N	GR	1	3	M	R	1
130		13.8	13	7.6	1311	1137.4	0.87	CK	M	M	L	L	BG	SA	GR	3	2	M	R	1
131		12.4	8.1	4.53	452.746	657.9	1.45	CK	R	M	VL	L	YR	N	GR	4	4	M	R	1
132		12.5	12	6.9	991.875	643.2	0.65	CK	M	M	VL	L	RB	N	GR	3	2	M	R	1
133		17	13	7.5	1657.5	1802.3	1.09	BCK	R	M	L	L	RB	N	GR	3	2	M	R	1
134		17.5	9.5	7	1163.75	1217.6	1.05	BCK	M	M	L	L	LBG	CH	GR	1	1	M	R	1
135		2.1	1.4	0.9	2.646	3066.6	1158.96	A	F	M	L	L	DG	N	M/	1	0	M	SL	600
136		4.25	2.1	2	17.85	3002	168.18	A	F	M	VL	L	BG	N	N	1	0	M	S	602
137		3.4	3.1	1.85	19.499	3056.2	156.74	A	F	M	N	L	DG	N	M/	0	0	M	S	606
138		4.8	3.7	3	53.28	1455.6	27.32	A	M	M	VL	M	RY	N	M/	1	4	M	R	100
139		3.2	3.2	1.76	18.0224	1466.6	81.38	P	M	M	VL	L	BG	N	M/	4	2	M	SS	98
140		6.1	5.8	3.4	120.292	1490.8	12.39	A	R	M	L	L	RB	N	N	6	4	M	VR	100
141		7.4	5.2	4.13	158.922	3850	24.23	L	F	M	VL	L	RG	N	M/	0	1	M	R	220
142		3.89	1.9	0.95	7.02145	3788	539.49	FN	F	M	VL	L	DG	N	N	2	0	M	SL	212
143		4.03	3.5	2.76	38.9298	3900	100.18	P	F	M	VL	L	LG	N	M/	2	0	M	S	218
144		3.9	2.5	1.8	17.55	2469	140.68	V	F	M	N	L	LG	N	M/	2	0	M	SL	221
145		8.13	6	4.76	231.806	309.8	1.34	CK	M	M	VL	L	LG	N	GR	3	2	M	R	1
146		8.13	6	4.76	231.806	302	1.30	CK	M	M	VL	L	LG	N	GR	3	2	M	R	1
147		8.13	6	4.76	231.806	312	1.35	CK	M	M	VL	L	LG	N	GR	3	2	M	R	1
148		8.13	6	4.76	231.806	342.1	1.48	CK	M	M	VL	L	LG	N	GR	3	2	M	R	1
149		10.6	9.8	6.5	675.22	299.3	0.44	CK	M	M	VL	L	YG	N	GR	3	2	M	R	1

150		10.6	9.8	6.5	675.22	306	0.45	CK	M	M	VL	L	YG	N	GR	3	2	M	R	1
151		10.6	9.8	6.5	675.22	309	0.46	CK	M	M	VL	L	YG	N	GR	3	2	M	R	1
152		10.6	9.8	6.5	675.22	389	0.58	CK	M	M	VL	L	YG	N	GR	3	2	M	R	1
153		8.9	8.2	6.1	445.178	356	0.80	CK	M	M	VL	L	RG	N	GR	3	2	M	R	1
154		8.9	8.2	6.1	445.178	361	0.81	CK	M	M	VL	L	RG	N	GR	3	2	M	R	1
155		8.9	8.2	6.1	445.178	306.2	0.69	CK	M	M	VL	L	RG	N	GR	3	2	M	R	1
156		5.02	4	2.86	57.4288	2333.3	40.63	A	R	M	L	M	YB	N	M/	3	4	M	R	35
157		4.6	1.9	1.3	11.362	2113.3	186.00	A	F	M	VL	L	LG	N	M/	3	1	M	SS	31
158		5.78	4.2	3	72.828	2221	30.50	A	F	M	VL	L	BG	N	M/	3	0	M	SS	24
159		9.17	6.9	3.14	198.965	9500	47.75	DE	F	M	VL	L	RG	N	M/	2	1	M	SS	475
160		5.38	3.8	2.56	51.7857	9506	183.56	A	F	M	VL	L	BG	N	M/	1	0	M	SS	476
161		4.5	3.3	3.21	46.9463	1500	31.95	A	M	M	VL	L	RG	N	M/	3	1	M	R	50
162		4.7	3.6	3.2	54.144	1469	27.13	A	M	M	VL	L	RB	N	M/	3	3	M	R	54
163		4.5	3.7	2.35	38.8103	1434	36.95	P	M	M	VL	L	RB	N	N	2	1	M	R	54
164		4.7	2.9	2.19	29.3351	1498	51.07	A	F	M	VL	L	RG	N	M/	3	3	M	SS	45
165		5.6	3.1	2.49	43.7842	2333.3	53.29	A	F	M	VL	L	RB	N	M/	2	2	M	SS	25
166		10.4	8	6.2	515.84	2190	4.25	A	M	M	VL	L	LG	N	M/	3	1	M	R	26
167		6.2	4.8	3.29	97.9104	2537.5	25.92	A	R	M	VL	L	YR	N	N	4	4	M	R	27
168	1	0.78	0.7	0.53	0.30592	6.2	20.27	D	F	M	VL	M	RG	N	N	0	1	M	SL	8
169	1	0.76	0.7	0.6	0.32832	6.4	19.49	D	F	M	VL	M	RG	N	N	0	1	M	SL	10
170	1	0.6	0.5	0.4	0.12	0.6	5.00	D	F	M	VL	M	BG	N	N	0	1	M	SL	1
171	1	0.69	0.6	0.45	0.17388	0.6	3.45	D	F	M	VL	M	BG	N	N	0	1	M	SL	1
172	1	0.6	0.5	0.4	0.12	0.4	3.33	D	F	M	VL	M	BG	N	N	0	1	M	SL	1
173	1	0.56	0.5	0.4	0.10528	0.3	2.85	D	F	M	VL	H	LG	N	N	0	1	M	S	1
174	1	0.55	0.5	0.4	0.1034	0.3	2.90	D	F	M	VL	H	LG	N	N	0	0	M	S	1
175	1	0.68	0.6	0.5	0.204	1.4	6.86	D	F	M	VL	N	BG	N	N	0	0	M	S	4
176	1	0.69	0.6	0.45	0.17388	3.3	18.98	D	F	M	VL	N	DG	N	M/	0	0	M	SL	10
177	1	1.09	0.7	0.62	0.44603	0.7	1.57	BE	F	M	VL	L	DG	N	M/	0	0	M	SL	1
178	1	1.15	0.8	0.42	0.36225	0.6	1.66	BE	F	M	VL	L	DG	N	M/	0	0	M	SL	1
179	1	1.19	0.8	0.59	0.54764	1.1	2.01	BE	F	M	VL	L	DG	N	M/	0	0	M	SL	1
180	1	1.01	0.5	0.43	0.23018	1.2	5.21	BE	F	M	VL	L	BG	N	M/	0	0	M	S	1
181	1	0.92	0.6	0.49	0.2795	0.9	3.22	BE	F	M	VL	L	BG	N	M/	0	1	M	S	1

182	1	1.3	0.9	0.7	0.819	5.2	6.35	8	F	M	VL	L	BG	N	M/	0	0	M	S	5
183	1	1.16	0.6	0.56	0.38976	5	12.83	8	F	M	VL	N	DG	N	M/	0	0	M	SL	9
184	1	1.6	1	0.6	0.9408	5.9	6.27	8	F	M	VL	L	RB	N	M/	1	1	M	S	2
185	1	3	1.9	1.3	7.41	8.6	1.16	S	F	M	VL	N	BG	N	M/	2	1	M	SS	1
186	1	2.76	2	0.7	3.80604	22.5	5.91	Y	F	M	VL	L	BG	N	M/	1	1	M	S	6
187	1	2.4	2	0.9	4.32	15.5	3.59	T	F	M	VL	N	BG	N	M/	1	1	M	S	3
188	1	1.88	1.3	0.5	1.1938	9.7	8.13	L	F	M	VL	L	BG	N	N	1	1	M	S	3
189	1	2.14	1.5	1.4	4.52396	26.2	5.79	H	F	M	VL	L	LG	N	M/	2	1	M	S	6
190	1	2	1.6	1.12	3.5616	11.9	3.34	A	F	M	VL	M	RB	SA	M/	1	3	M	SS	5
191	1	2	1.6	1.2	3.816	36.7	9.62	A	F	M	VL	L	BG	N	M/	1	2	M	S	12
192	1	1.2	1.1	0.9	1.188	66.4	55.89	A	F	M	VL	N	DG	N	M/	0	1	M	SL	43
193	4	6.07	2.7	2.25	36.4655	46.1	1.26	FS	M	M	VL	VL	DG	N	M/	3	1	M	S	1
194	4	4.1	3.4	2	27.88	16.3	0.58	R	F	M	VL	L	DG	N	M/	2	1	M	S	1
195	4	3.4	3.4	1.3	15.028	11	0.73	X	F	M	VL	L	BG	N	M/	2	3	M	S	1
196	4	3	2	1.3	7.8	4.1	0.53	AN	F	M	VL	L	BG	N	M/	1	2	M	S	1
197	4	1.9	1.5	0.7	1.995	4.6	2.31	L	F	M	VL	L	LG	N	N	1	1	M	SL	2
198	4	7.2	4.1	2.9	85.608	282.4	3.30	P	M	M	VL	L	BG	N	M/	2	2	M	SR	6
199	4	3.6	1.8	1.2	7.776	72.6	9.34	P	F	M	VL	L	BG	N	M/	2	1	M	SS	9
200	4	7.8	3.8	3.1	91.884	411.7	4.48	CK	R	M	L	M	RB	N	M/	4	5	M	R	6
201	4	7.1	4.8	3.4	115.872	114.9	0.99	A	M	M	L	M	RB	N	M/	4	5	M	R	1
202	4	5.6	2.6	2.3	33.488	266.4	7.96	A	M	M	VL	L	RG	N	M/	2	2	M	SR	5
203	4	0.6	0.5	0.5	0.15	2.1	14.00	D	F	M	VL	N	DG	N	M/	1	1	M	SL	3
204	4	2.2	2	1.3	5.72	16.1	2.81	V	M	M	VL	L	BG	N	M/	2	3	M	S	2
205	4	3.3	3.2	1.6	16.896	87.5	5.18	A	M	M	VL	L	YG	N	M/	1	3	M	SS	10
206	4	2.9	2	3.6	20.88	35	1.68	A	M	M	VL	L	RB	N	M/	5	4	M	R	6
207	4	1.9	1.8	0.9	3.078	30.5	9.91	A	F	M	VL	L	LG	N	M/	2	1	M	S	8
208	4	3.2	2.3	2	14.72	166	11.28	A	M	M	VL	M	RB	N	M/	5	5	M	R	10
209	4	3.1	2.7	1.9	15.903	166.3	10.46	A	M	M	VL	L	RG	N	M/	3	4	M	SR	16
210	4	2.7	2.1	1.4	7.938	72.9	9.18	A	M	M	VL	L	YG	N	M/	3	3	M	R	8
211	4	3.1	2.4	1.7	12.648	68.3	5.40	A	M	M	VL	L	RG	N	M/	2	2	M	R	5
212	4	3.3	1.9	1.6	10.032	30	2.99	A	M	M	VL	L	DG	N	M/	1	1	M	SL	8
213	4	3.3	2.2	1.4	10.164	36.6	3.60	A	M	M	VL	L	OG	N	M/	2	1	M	S	8

214	4	1.8	2.9	0.9	4.698	23.9	5.09	A	M	M	VL	L	BG	N	M/	1	3	M	S	5
215	4	3.57	2.4	2	17.136	67.9	3.96	A	M	M	L	M	BR	N	N	4	2	M	R	5
216	4	3.9	2.7	2.1	22.113	40.1	1.81	A	F	M	VL	L	RG	N	M/	1	4	M	S	3
217	4	5	3.7	2.6	48.1	127	2.64	H	M	M	VL	L	LG	N	M/	3	2	M	SR	4
218	4	4	1.3	0.8	4.16	19.8	4.76	CS	F	M	VL	L	YG	N	M/	1	2	M	S	5
219	4	2.4	0.8	0.6	1.1376	5.8	5.10	SS	F	M	VL	L	DG	N	M/	1	1	M	SL	3
220	5	4.5	3.5	3	47.25	32.7	0.69	Y	M	M	VL	L	RG	N	M/	4	3	M	R	1
221	5	3.4	2.1	1.4	9.996	6.8	0.68	SS	F	M	VL	L	DG	N	M/	3	2	M	SS	1
222	5	3.1	1.9	0.4	2.356	4.7	1.99	M	M	M	VL	N	LG	N	WO	1	1	M	S	1
223	5	2.3	1.6	0.4	1.472	2.8	1.90	M	M	M	VL	N	BG	N	WO	2	1	M	SS	1
224	5	2.58	2.3	1.55	9.1977	7	0.76	L	F	M	VL	N	DG	N	M/	1	3	M	S	1
225	5	2.8	2.6	1.5	10.92	10.4	0.95	T	M	M	VL	L	BG	N	N	2	3	M	S	1
226	5	4.1	3	2.1	25.83	25.4	0.98	H	M	M	VL	L	BG	N	M/	1	1	M	S	1
227	5	1.7	1	0.8	1.36	1.2	0.88	H	F	M	VL	L	RG	N	FL	1	2	M	SL	1
228	5	2.19	1.4	1.2	3.78432	4.1	1.08	FN	F	M	VL	N	LG	N	M/	2	3	M	S	1
229	5	2.98	1.6	1.12	5.27341	7.1	1.35	A	F	M	VL	L	BG	N	M/	1	2	M	S	4
230	5	0.76	0.6	0.59	0.28249	6	21.24	D	F	M	VL	M	BG	N	M/	1	1	M	SL	15
231	6	2.6	0.5	0.48	0.624	4.9	7.85	S	F	M	VL	N	BG	N	M/	0	0	M	S	2
232	7	7.76	3.7	2.27	64.4716	107.2	1.66	L	F	M	VL	L	BG	N	M/	2	1	M	SS	2
233	7	4.09	2	2	16.36	89	5.44	A	F	M	VL	L	BG	N	M/	0	2	M	S	8
234	7	3.5	2	1.5	10.5	19.5	1.86	A	F	M	VL	L	BG	N	M/	3	4	M	S	3
235	7	2	0.8	0.7	1.12	13.2	11.79	A	M	M	VL	L	OG	N	M/	4	2	M	SS	8
236	7	1.4	1	0.8	1.12	1.4	1.25	A	R	M	L	M	RG	N	M/	5	6	M	R	1
237	1	8.4	6.8	6.4	365.57	1678.1	4.59	A	M	M	VL	L	YG	N	M/	1	1	M	R	88
238	1	2	2	1.26	5.04	1701.7	337.64	A	M	M	VL	L	YG	N	M/	2	1	M	SS	75
239	1	3	2.9	2.5	21.75	1498.1	68.88	A	M	M	VL	M	YG	N	M/	3	4	M	S	74
240	1	5.7	3.9	3.2	71.14	1569.2	22.06	A	M	M	VL	L	RB	N	M/	0	2	M	VR	76
241	2	5.7	3.2	2.4	43.37	1666.6	38.43	P	M	M	VL	L	YG	N	N	4	1	M	R	69
242	2	8.3	7.7	5.6	357.90	1166.6	3.26	P	F	M	VL	L	BG	N	M/	0	0	M	R	63
243	2	4.6	4.2	2.4	46.37	1160	25.02	A	F	M	VL	L	RG	N	M/	4	2	M	S	62
244	2	5	3.5	2.5	43.75	1192	27.25	A	F	M	VL	L	DG	N	M/	2	0	M	S	64
245	3	1.78	1.8	0.66	2.08	1168	561.70	A	F	M	N	L	BG	N	M/	1	0	M	S	69

246	3	3.9	2.3	2.1	18.84	1201	63.76	A	F	M	VL	L	RG	N	M/	2	1	M	S	71
247	3	5.5	3.4	2.7	50.49	1269	25.13	P	F	M	VL	L	YG	N	M/	3	0	M	S	56
248	3	13.6	11	8.57	1235.45	1034.5	0.84	CK	R	M	L	L	YB	N	GR	3	4	M	R	1
249	3	4.6	3.8	3	52.44	1200	22.88	A	R	M	L	M	RY	N	M/	3	4	M	R	82
250	3	1.8	1.1	1.1	2.18	800	367.31	A	R	M	L	M	RY	N	M/	3	4	M	R	78
251	3	6.6	6.5	3.3	141.57	900	6.36	A	F	M	VL	L	RG	N	M/	3	2	M	SS	37
252	4	3.6	3	1.4	15.12	800	52.91	A	F	M	VL	L	DG	N	M/	1	0	M	SL	36
253	4	4	2.9	2.3	26.68	700	26.24	A	M	M	VL	L	YG	N	M/	2	2	M	SS	35
254	4	2.9	2.9	2.4	20.18	600	29.73	A	R	M	L	L	YG	N	M/	2	3	M	R	34
255	4	15	8.2	6.58	808.35	754.4	0.93	CK	M	M	VL	L	BG	SA	GR	2	1	M	R	1
256	4	12.8	10	6.66	861.00	945.4	1.10	CK	M	M	VL	L	DG	N	GR	3	1	M	R	1
257	4	7.83	5.6	1.76	77.72	98.5	1.27	CK	M	M	VL	L	DG	N	GR	3	0	M	R	1
258	4	13.14	1.3	5.81	98.48	858.6	8.72	CK	M	M	VL	L	BG	N	GR	3	2	M	R	1
259	5	9.93	7.8	6.11	472.64	472.2	1.00	CK	M	M	VL	L	DG	N	GR	2	0	M	R	1
260	5	11	7.3	6.4	516.74	495	0.96	CK	M	M	VL	L	DG	N	GR	3	0	M	R	1
261	5	9.3	8.1	5.3	399.25	344.5	0.86	CK	R	M	L	L	DG	CH	GR	2	0	M	R	1
262	5	8.5	6.7	4.81	272.29	296.5	1.09	CK	M	M	VL	L	DG	N	GR	0	0	M	R	1
263	5	10.5	7.3	6.8	521.22	733.1	1.41	CK	M	M	VL	L	BG	N	GR	3	1	M	R	1
264	5	7.79	7.4	4.3	247.88	221.4	0.89	CK	M	M	VL	N	DG	N	GR	1	0	M	R	1
265	5	8	6.3	5	252.00	247.6	0.98	CK	M	M	VL	L	BG	N	GR	1	1	M	SS	1
266	5	8.6	6.1	3.27	171.26	187.3	1.09	CK	M	M	VL	L	YG	N	GR	3	3	M	R	1
267	5	8.7	6.1	4	212.28	199.6	0.94	CK	M	M	VL	L	BG	N	GR	2	2	M	R	1
268	5	8	5.5	5.1	224.40	248.9	1.11	CK	M	M	VL	L	BG	N	GR	2	2	M	R	1
269	5	9.3	6.1	5.7	323.36	466	1.44	CK	M	M	VL	L	BG	N	GR	2	2	M	R	1
270	5	7.5	6.3	3.69	174.35	161.6	0.93	CK	M	M	VL	L	BG	CH	GR	2	2	M	R	1
271	5	6.6	4.3	2.5	70.95	83.1	1.17	CK	M	M	VL	L	BG	N	GR	2	2	M	R	1
272	5	8.6	5.7	5.3	259.81	1666.6	6.41	CK	M	M	VL	L	YG	N	GR	2	3	M	R	70
273	6	2.95	2.4	1.52	10.58	30.9	2.92	A	R	M	L	M	YR	N	N	4	5	M	R	7
274	6	2.15	1.7	1.4	5.06	28.2	5.58	A	M	M	VL	M	BG	N	M/	3	2	M	SS	8
275	6	1.24	0.8	0.48	0.45	1	2.24	BE	F	M	VL	M	BG	N	M/	0	1	M	S	1
276	6	2.88	1.5	0.87	3.86	2.6	0.67	L	M	M	VL	M	LG	N	M/	1	2	M	S	1
277	6	5.1	4.2	1.3	27.85	20.8	0.75	Y	M	M	VL	L	BG	N	M/	1	2	M	SS	1

278	6	4.9	4	3	58.80	37.4	0.64	A	M	M	VL	M	RB	WO	M/	3	3	M	R	1
279	6	3.9	3.9	3.96	60.08	13.7	0.23	ST	M	M	L	N	BY	TU	N	2	5	M	R	1
280	6	3.14	2.2	1.4	9.67	16.3	1.69	A	M	M	VL	L	RG	N	M/	1	3	M	SS	2
281	6	2.8	2.4	0.76	5.11	39.3	7.70	A	F	M	VL	L	BG	N	M/	2	2	M	SS	7
282	6	0.6	1	2.3	1.38	38.8	28.12	A	F	M	VL	L	BG	N	M/	2	2	M	S	20
283	7	2.9	2.7	1.6	12.53	2.5	0.20	A	F	M	VL	L	BG	N	M/	1	3	M	SS	4
284	7	3.6	3	2.1	22.68	11.8	0.52	ST	R	M	VL	H	RG	TU	N	4	4	M	R	1
285	7	4.77	3	2.3	33.02	37.5	1.14	CK	R	M	VL	H	YR	N	N	3	5	M	R	1
286	7	5.62	3.7	1.78	36.81	29.2	0.79	CK	R	M	VL	H	YR	SA	N	1	5	M	R	1
287	7	3.7	3.6	2.43	32.01	111.1	3.47	A	R	M	VL	H	RG	WO	N	4	3	M	R	3

Appendix 2b: Attribute (Physical) Analysis of Smelting Slag from Msete Site

Analysis No.	Bag No.	Length (cm)	Width (cm)	Thickness (cm)	Volume (cc)	Mass (g)	Density (g/cc)	Morphology	Thermal Condition	Luster	Porosity	Magnetism	Color	Inclusions	Impressions	Fragmentation	Weathering	Raw Material	Surface Condition	Quantity
1		14	11.4	8.3	1325	169.4	0.128	ST	M	M	VL	M	YB	TU	M/	3	1	M	R	1
2		17	14.5	7.18	1770	2024.3	1.144	CK	F	M	VL	M	YB	N	GR	2	1	M	SS	1
3		23	12.5	9	2588	2005.7	0.775	CK	M	M	VL	M	RG	N	GR	2	1	M	R	1
4		18.5	12.5	6.4	1480	1279.5	0.865	CK	R	M	L	L	RB	N	GR	2	1	M	R	1
5		19	12	7.88	1797	4374.0	2.435	ST	M	M	L	L	RG	N	M/	4	2	M	R	2
6		18.5	12.5	8.84	2044	2134.4	1.044	A	M	M	M	M	RB	TU	N	2	3	M	R	1
7		12.3	9.37	6.69	771	2054.0	2.664	A	M	M	L	L	DG	N	M/	4	1	M	R	6
8		12.3	9.37	6.69	771	948.6	1.23	P	M	M	L	L	DG	N	M/	4	1	M	R	1
9		14.7	11.4	6.46	1083	11000.0	10.16	A	M	M	N	N	RB	N	M/	4	2	M	R	11
10		12	8	7.8	748.8	6000.0	8.013	ST	F	M	L	L	LG	N	M/	4	1	M	S	5
11		18	10	10	1800	6000.0	3.333	BA	F	M	M	M	RG	N	M/	4	3	M	R	2
12		30	21	7	4410	9600.0	2.177	BP	M	M	L	L	DG	N	GR	4	1	M	S	1
13		10.8	7.6	4.3	352.9	4800.0	13.6	A	M	M	L	L	RG	N	M/	1	3	M	SS	12

14		16	14	9.5	2128	2500.0	1.175	A	M	M	L	L	DG	N	M/	2	2	M	R	1
15		16	14	9.5	2128	2500.0	1.175	ST	M	M	L	L	DG	N	M/	3	2	M	R	1
16		5.98	4.8	4.2	120.6	1600.0	13.27	A	M	M	L	L	DG	N	M/	3	2	M	SS	19
17		6.6	4.2	2.3	63.76	3200.0	50.19	A	M	M	L	L	RG	N	M/	3	2	M	SS	78
18		11.7	6.2	3.9	282.9	7900.0	27.92	A	C	M	L	L	BG	N	M/	5	3	M	R	36
19		6	5.89	3.9	137.8	5400.0	39.18	A	M	M	L	L	DG	N	M/	3	1	M	SS	50
20		11.7	7.7	6.85	617.1	14100.0	22.85	A	M	M	L	L	RG	N	M/	4	4	M	R	74
21		11.2	8.2	6.7	616.4	3800.0	6.165	A	M	M	L	L	DG	N	M/	2	1	M	SS	3
22		16	11.5	8	1472	2078.8	1.412	P	M	M	L	L	RG	N	N	3	2	M	SS	1
23		11.2	7.43	7.3	604.8	832.2	1.376	A	M	M	L	L	RG	ST	M/	2	2	M	R	1
24		4	3	1.76	21.12	3300.0	156.3	A	F	M	L	L	RG	N	TU	2	1	M	S	162
25		6	4.4	3.88	102.4	3600.0	35.15	A	F	M	L	L	RG	N	FL	2	1	M	S	40
26		9.31	8	5.18	385.8	600.0	1.555	A	M	M	L	L	RG	N	FL	2	1	M	SS	1
27		7.94	5.66	3.94	177.1	5600.0	31.63	A	C	M	L	L	BG	N	M/	3	2	M	R	150
28		21	12	9.5	2394	3088.3	1.29	BA	M	M	L	L	ORG	N	M/	4	2	M	SS	1
29		6.8	5.5	3.95	147.7	3000.0	20.31	A	F	M	L	L	DG	N	M/	2	1	M	SS	106
30		6.5	3.8	1.9	46.93	523.6	11.16	A	M	M	L	L	YG	N	M/	3	4	M	SS	9
31		3.7	2.5	2.39	22.11	6200.0	280.4	A	M	M	L	L	RG	N	M/	3	1	M	R	300
32		9	6.15	2.8	155	2600.0	16.78	A	M	M	L	L	RG	N	M/	3	1	M	R	40
33		7.7	5.6	4	172.5	3800.0	22.03	A	C	M	VL	L	RG	N	M/	3	2	M	R	20
34		4.86	4.07	2.62	51.82	2600.0	50.17	A	M	M	VL	L	DG	N	M/	3	1	M	SS	86
35		21.5	15	12	3870	4600.0	1.189	ST	F	M	VL	L	RG	N	M/	3	1	M	S	1
36		3.26	2.11	1.26	8.667	6000.0	692.3	A	M	M	VL	L	BG	N	M/	2	1	M	SS	300
37		3.38	2.38	1.19	9.573	5000.0	522.3	A	M	M	L	L	BG	N	M/	3	2	M	R	370
38		4.2	2.54	2.3	24.54	1200.0	48.91	A	M	M	VL	L	BG	N	M/	4	3	M	R	80
39		1.2	0.9	0.6	0.648	2000.0	3086	A	F	M	VL	L	DG	N	N	4	0	M	SL	390
40		2.8	2.2	1.5	9.24	1200.0	129.9	A	M	M	L	L	GB	N	N	2	4	M	R	346
41		1.6	1	0.7	1.12	3500.0	3125	A	F	M	VL	L	DG	N	N	1	0	M	SL	600
42		4.7	3	2.9	40.89	3800.0	92.93	A	M	M	VL	L	RG	N	M/	3	2	M	R	473
43		4.7	4.5	2.79	59.01	2800.0	47.45	A	M	M	VL	L	DG	N	M/	2	1	M	SS	132
44		4.5	3.2	1.6	23.04	2000.0	86.81	A	R	M	VL	L	YB	N	M/	3	4	M	R	179
45		5	4.7	3.1	72.85	1800.0	24.71	A	C	M	L	L	BG	N	M/	3	1	M	R	63

46		11.1	9.11	7.8	785.2	1497.8	1.908	CK	M	M	VL	M	YG	N	M/	2	0	M	R	1
47		18.1	13.66	8.21	2024	1506.0	0.744	ST	M	M	VL	M	BG	N	N	1	0	M	R	1
48		17	10.68	7.12	1289	1554.2	1.206	CK	R	M	VL	H	DG	N	M/	2	2	M	R	1
49		13.1	11.64	8.68	1325	1197.7	0.904	ST	M	M	VL	H	YG	N	N	3	2	M	R	1
50		11.6	9.56	5.55	617.6	643.0	1.041	CK	R	M	VL	H	DB	N	N	3	2	M	R	1
51		10.6	8.93	6.03	571.3	756.1	1.323	CK	R	M	VL	H	DB	N	M/	2	2	M	SS	1
52		9.76	9.6	5.14	481.6	397.7	0.826	CK	M	M	VL	H	DB	N	M/	3	2	M	SS	1
53		8.14	6.31	4.41	226.5	238.3	1.052	CK	R	M	VL	H	DB	N	M/	3	3	M	SR	1
54		9.93	5.57	3.12	172.6	165.8	0.961	CK	M	M	VL	H	DB	N	M/	2	3	M	R	1
55		8.77	6.93	3.1	188.4	257.0	1.364	CK	M	M	VL	H	YG	N	M/	3	1	M	R	1
56		7.02	6.5	3.83	174.8	237.7	1.36	A	M	M	VL	M	BG	N	M/	2	2	M	SS	1
57		7.1	2.98	2.63	55.65	109.1	1.961	A	M	M	VL	M	YB	N	N	2	2	M	R	1
58		8.8	6.67	2.6	152.6	1186.8	7.777	TS	M	M	VL	M	DB	TU	N	1	3	TU	SS	1
59	1	4.33	2.6	1.6	18.01	39.5	2.193	H	M	M	VL	L	DG	N	M/	1	1	M	S	3
60	1	5.43	4.6	1.9	47.46	52.4	1.104	P	M	M	VL	L	RG	N	M/	1	1	M	S	3
61	1	5	2.53	1	12.65	15.9	1.257	K	M	M	VL	L	DG	N	M/	2	1	M	SL	1
62	1	3.2	2.4	1.56	11.98	7.0	0.584	4	M	M	VL	L	BG	N	M/	1	2	M	SS	1
63	1	3.9	1.6	0.8	4.992	36.7	7.352	Y	M	M	VL	L	DG	N	M/	1	1	M	S	5
64	1	3.68	1.5	0.8	4.416	10.3	2.332	FN	F	M	VL	L	DG	N	M/	1	0	M	SL	1
65	1	3.5	2.6	1.3	11.83	7.1	0.6	S	F	M	VL	L	BG	N	M/	2	1	M	SS	1
66	1	3	1.4	0.9	3.78	7.7	2.037	SS	F	M	VL	N	DB	N	M/	2	0	M	S	4
67	1	4.5	2.9	2	26.1	171.9	6.586	A	F	M	VL	L	RG	SA	M/	1	1	M	S	8
68	1	3.8	1.6	0.6	3.648	29.0	7.95	L	F	M	VL	L	DG	N	M/	1	1	M	S	4
69	1	3.5	2.4	1	8.4	7.5	0.893	L	M	M	VL	H	RB	N	N	0	4	M	R	2
70	1	4.3	2.6	1.3	14.53	39.3	2.704	H	M	M	VL	L	BG	N	M/	2	2	M	SS	3
71	1	1	0.7	0.6	0.42	3.4	8.095	D	F	M	VL	M	BG	N	M/	0	1	M	S	7
72	1	1.2	0.8	0.6	0.576	9.6	16.67	A	F	M	VL	M	DG	N	M/	1	1	M	S	8
73	2	6.4	1.5	1.1	10.56	33.7	3.191	SS	M	M	VL	L	BG	N	M/	1	4	M	SS	1
74	2	6.3	3.9	3.1	76.17	163.2	2.143	A	F	M	VL	VL	DG	N	M/	2	1	M	S	3
75	2	7.8	4	2.2	68.64	198.4	2.89	P	M	M	VL	L	BG	N	M/	1	2	M	R	3
76	2	2.2	1.9	1.5	6.27	27.2	4.338	A	M	M	VL	L	BG	N	M/	1	1	M	S	4
77	2	0.4	0.4	0.3	0.048	0.6	12.5	D	F	M	VL	H	BG	N	N	0	0	M	SL	4

78	2	0.35	0.34	0.33	0.039	0.1	2.546	D	F	M	VL	H	DG	N	N	0	0	M	SL	2
79	2	0.65	0.6	0.6	0.234	4.0	17.09	D	F	M	VL	M	BG	N	N	1	4	M	S	6
80	2	1.1	0.9	0.6	0.594	8.1	13.64	A	F	M	VL	L	BG	N	M/	1	3	M	S	9
81	3	4.5	2.4	1.4	15.12	20.2	1.336	L	M	M	VL	L	RB	N	M/	2	4	M	SS	1
82	3	6.4	3.1	2.3	45.63	69.5	1.523	P	F	M	VL	VL	DG	N	M/	2	1	M	S	2

Appendix 2c: Attribute (Physical) Analysis of Smithing Slag from Nundu Site

Analysis No.	Bag No.	Length (cm)	Width (cm)	Thickness (cm)	Volume (cc)	Mass (g)	Density (g/cc)	Morphology	Thermal Condition	Luster	Porosity	Magnetism	Color	Inclusions	Impressions	Fragmentation	Weathering	Raw Material	Surface Condition	Quantity
1	1	11.1	7.63	3.5	296.43	1800	6.07	A	C	M	VL	M	DB	CH	N	2	4	M	R	10
2	1	8.6	8.2	4.2	296.18	2200	7.43	CK	C	M	VL	H	BY	CH	GR	1	4	M	R	22
3	1	7.7	5.8	3	133.98	1120	8.36	CK	C	M	VL	H	RB	SA	GR	2	5	M	R	17
4	1	5.8	4.1	2.6	61.83	1307	21.14	CK	M	M	VL	M	BG	N	GR	2	4	M	SS	14
5	1	4.96	3.64	2.51	45.32	806	17.79	A	M	M	VL	M	BG	SA	N	1	5	M	SR	19
6	1	5	3.8	2	38.00	404	10.63	A	M	M	VL	H	BG	N	M/	1	4	M	R	16
7	1	3.6	3.2	2.46	28.34	310	10.94	A	C	M	VL	M	YB	N	M/	0	5	M	R	19
8	1	2.7	2.6	1.7	11.93	30	2.51	A	C	M	VL	L	RG	N	WO	4	4	M	SS	3
9	1	2.4	1.4	1	3.36	16	4.76	A	M	M	VL	M	RB	N	M/	3	4	M	SR	7
10	1	1.8	1.7	1.4	4.28	39	9.10	A	C	M	VL	L	RB	N	M/	2	5	M	SR	13
11	2	5.3	3.3	1.6	27.98	129	4.61	A	C	M	VL	M	WB	TU	M/	2	3	M/TU	R	30
12	2	6.48	5.76	4	149.30	75.2	0.50	A	M	M	VL	M	DB	N	M/	0	5	M	SS	1
13	2	2.1	1.8	0.92	3.48	48.2	13.86	A	C	M	VL	L	YR	SA	M/	5	4	M	SR	21
14	2	3.6	2.1	1.6	12.10	24.3	2.01	A	C	M	VL	M	RY	N	N	1	5	M	R	5
15	2	2	2	1.46	5.84	13.8	2.36	A	M	M	VL	L	DG	N	M/	3	2	M	R	3
16	2	3	2.7	1.1	8.91	158	17.69	A	M	M	VL	M	YB	N	M/	1	4	M	SS	28
17	2	2.9	2.1	1.6	9.74	80.4	8.25	A	C	M	VL	M	DB	SA	M/	1	3	M	R	10

18	2	2.8	1.4	1.3	5.10	21.4	4.20	A	M	M	VL	L	YR	N	M/	1	4	M	SS	4
19	2	2.9	1.9	1.7	9.37	153	16.33	A	M	M	VL	L	RB	N	M/	4	3	M	R	17
20	2	2.4	2.1	1.2	6.05	213	35.15	A	C	M	VL	N	DB	N	M/	2	4	M	R	26
21	2	0.5	0.49	0.3	0.07	0.7	9.52	D	M	M	VL	H	BG	N	N	0	3	M	S	3
22	2	3.4	2.8	2.2	20.94	94.4	4.51	A	C	M	VL	M	R	N	M/	3	5	M	R	5
23	2	2.6	2.1	1.04	5.68	52.5	9.25	A	M	M	VL	H	RB	N	M/	3	5	M	R	15
24	2	2.2	1.3	0.7	2.00	7.2	3.60	A	M	M	VL	L	RB	SA	N	0	3	M	SS	3
25	2	2.49	1.71	1.33	5.66	87.8	15.50	A	C	M	VL	H	RB	SA	N	4	5	M	R	90
26	2	1.3	1.1	0.9	1.29	59.4	46.15	D	M	M	N	H	RB	N	M/	1	5	M	S	30
27	2	2.5	1.2	0.6	1.80	1.4	0.78	SE	M	M	L	L	DB	SA	M/	0	3	M	SS	1
28	3	0.91	0.76	0.11	0.08	<0.1	1.25	SC	M	M	VL	H	LG	N	N	5	4	M	S	1
29	3	0.8	0.6	0.2	0.10	<0.1	1.00	SC	M	M	VL	H	BG	N	N	4	3	M	S	5
30	3	0.6	0.5	0.1	0.03	<0.1	3.33	SC	M	M	VL	H	LG	N	N	3	4	M	S	6
31	3	0.5	0.4	0.09	0.02	<0.1	5.00	SC	M	M	VL	H	LG	N	N	3	5	M	S	7
32	3	0.44	0.41	0.08	0.01	<0.1	10.00	SC	M	M	VL	H	DG	N	N	5	4	M	S	1
33	3	0.38	0.3	0.04	0.005	<0.1	20.00	SC	M	M	VL	H	LG	N	N	4	5	M	S	5
34	3	0.42	0.4	0.4	0.07	0.1	1.49	D	M	M	VL	H	LG	N	N	0	3	M	S	3
35	3	0.53	0.45	0.31	0.07	0.1	1.35	D	M	M	N	H	LG	N	N	4	3	M	S	3
36	3	0.7	0.5	0.4	0.14	0.2	1.43	D	M	M	N	H	BG	N	M/	1	4	M	S	2
37	3	1.4	1.2	0.6	1.01	0.7	0.69	A	M	M	VL	H	BG	N	M/	3	4	M	R	1
38	3	0.6	0.3	0.22	0.04	0.3	7.58	A	M	M	VL	H	BG	SA	M/	3	3	M	SR	4
39	3	1	0.47	0.5	0.24	0.2	0.85	A	M	M	VL	M	RY	N	M/	1	6	M	SS	1
40	3	7.3	7.2	3.7	194.47	143	0.74	A	C	M	VL	H	BR	SA	GR	2	5	M	R	1
41	3	3.3	1.4	1.3	6.01	11.6	1.93	A	C	M	VL	M	LB	CH	M/	2	4	M	R	1
42	3	2.6	1.5	0.9	3.51	6.4	1.82	A	C	M	VL	L	YB	SA	M/	1	5	M	R	2
43	4	1.58	1.1	0.3	0.52	2.2	4.22	SC	M	M	VL	H	BG	N	M/	4	3	M	S	4
44	4	1.113	0.8	0.12	0.11	1.7	15.91	SC	M	M	VL	H	BG	N	M/	5	3	M	S	9
45	4	0.57	0.5	0.07	0.02	<0.1	<5	SC	M	M	VL	H	RB	N	M/	5	6	M	S	6
46	4	0.4	0.29	0.05	0.01	<0.1	<10	SC	M	M	VL	H	RG	N	M/	4	4	M	S	27
47	4	0.2	0.19	0.05	0.00190	<0.1	<52.63	SC	M	M	VL	H	DR	N	M/	5	4	M	S	5
48	4	1.15	0.8	0.5	0.46	1.2	2.61	A	C	M	VL	H	RB	N	M/	3	2	M	R	3
49	4	0.6	0.5	0.4	0.12	<0.1	<0.83	A	M	M	VL	M	RB	N	N	4	5	M	SR	5

50	4	0.96	0.8	0.8	0.61	6.1	9.93	D	M	M	N	H	BG	N	M/	0	3	M	S	8
51	4	0.67	0.6	0.5	0.20	6.2	30.85	D	M	M	N	H	BG	N	M/	0	4	M	S	24
52	4	0.68	0.5	0.46	0.16	2.6	16.62	D	M	M	N	H	BG	N	M/	2	3	M	S	10
53	4	0.29	0.29	0.2	0.02	0.5	29.73	D	M	M	N	H	DG	N	M/	0	2	M	S	7
54	4	2.1	1.6	1.36	4.57	44.5	9.74	A	M	M	VL	M	YB	SA	M/	2	3	M	R	24
55	4	1.32	1.1	0.59	0.86	20.1	23.46	A	M	M	VL	M	YG	SA	M/	3	2	M	SR	19
56	4	2.3	1.7	1	3.91	27.5	7.03	A	C	M	VL	H	YR	N	N	4	5	M	R	12
57	4	0.92	0.26	0.79	0.19	31.1	164.58	A	C	M	VL	H	YR	N	N	4	4	M	R	41

Appendix 2d: Attribute (Physical) Analysis of Smithing Slag from Mpembani Site

Analysis No.	Bag No.	Length (cm)	Width (cm)	Thickness (cm)	Volume (cc)	Mass (g)	Density (g/cc)	Morphology	Thermal Condition	Luster	Porosity	Magnetism	Color	Inclusions	Impressions	Fragmentation	Weathering	Raw Material	Surface Condition	Quantity
1	1	1.96	1.57	0.94	2.89	78.3	27.07	A	C	M	L	N	WG	SA	M/	3	2	M	R	22
2	1	6.56	5.27	1.71	59.12	115	1.94	A	C	M	L	L	RG	CH	GR	3	3	M	R	24
3	1	10	8.6	3.8	326.80	463	1.42	CK	C	M	L	M	RB	N	GR	2	2	M	R	4
4	1	9.6	5.6	3.4	182.78	143	0.78	A	C	M	VL	H	RG	Fe	M/	1	4	M	R	1
5	1	7.5	5.6	3.4	142.80	98	0.69	A	C	M	L	M	WG	TU	N	1	5	M	R	1
6	1	5.8	4.84	2.38	66.81	109	1.62	CK	C	M	VL	M	RG	N	GR	3	5	M	R	2
7	1	6.4	4.2	2.3	61.82	77.1	1.25	A	C	M	VL	L	WB	N	M/	2	3	M	R	3
8	1	0.71	0.65	0.55	0.25	3.7	14.58	D	M	M	N	H	LG	N	M/	0	1	M	S	10
9	1	1.33	0.9	0.7	0.84	4.6	5.49	D	M	M	N	M	WG	N	M/	0	2	M	S	5
10	1	1.3	0.92	0.73	0.87	6.9	7.90	D	M	M	N	M	LG	N	M/	0	2	M	R	5
11	1	4.6	3.1	2.44	34.79	154	4.42	A	C	M	L	L	RB	N	M/	3	3	M	SL	14
12	1	2.26	1.56	1	3.53	32.8	9.30	A	M	M	VL	L	WG	N	M/	1	1	M	SL	7
13	1	3.27	2	1.15	7.52	36.1	4.80	A	M	M	VL	L	BG	N	M/	1	2	M	R	16
14	1	1.36	0.9	0.8	0.98	66.2	67.61	A	C	M	VL	M	BG	SA	M/	4	2	M	R	22

15	1	1.3	0.86	0.75	0.84	382	455.93	A	C	M	VL	M	WB	SA	M/	4	2	M	S	182
16	2	1.7	0.57	0.19	0.18	0.3	1.63	SC	M	M	VL	H	G	N	M/	3	1	M	S	1
17	2	1.13	0.58	0.03	0.02	0.5	25.43	SC	M	M	VL	H	G	N	N	3	1	M	S	14
18	2	1.62	1.14	0.12	0.22	2.2	9.93	SC	M	M	VL	H	G	N	N	3	1	M	S	6
19	2	0.34	0.19	0.01	0.00	1.5	2321.98	SC	M	M	VL	H	G	N	N	2	1	M	S	70
20	2	0.69	0.39	0.03	0.01	1.5	185.80	SC	M	M	H	H	RG	N	N	4	2	M	S	81
21	2	0.21	0.17	0.01	0.0004	1.6	4481.79	SC	M	M	VL	H	G	N	N	4	0	M	S	63
22	2	0.57	0.56	0.46	0.15	1.8	12.26	D	M	M	VL	H	RG	N	M/	0	2	M	S	7
23	2	0.72	0.62	0.58	0.26	1.8	6.95	D	M	M	VL	H	RG	N	M/	0	1	M	S	4
24	2	1.4	1.1	0.82	1.26	5.7	4.51	A	C	M	VL	L	WG	SA	N	3	2	M	R	13
25	2	1.73	1.17	0.9	1.82	18.3	10.05	A	C	M	VL	L	RG	N	M/	4	1	M	R	31
26	2	1.48	1.1	1.02	1.66	0.9	0.54	A	C	M	VL	M	RY	N	N	4	3	M	R	2
27	3	5	2.96	1.63	24.12	28.2	1.17	A	M	M	VL	H	RG	Fe	N	1	5	M	R	1
28	3	3.98	1.8	1.6	11.46	6.3	0.55	A	M	M	VL	H	GR	Fe	N	1	3	M	R	1
29	3	2.88	1.7	8.47	41.47	1.4	0.03	A	M	M	VL	H	WR	Fe	N	2	2	M	R	1
30	3	3.79	2.79	1.15	12.16	13.9	1.14	A	F	M	VL	M	DG	N	Fe	1	1	M	SS	4
31	3	3.2	1.02	0.62	2.02	17.2	8.50	A	F	M	VL	H	RG	N	Fe	1	3	M	SS	5
32	3	2	1.26	0.76	1.92	13.7	7.15	A	F	M	VL	VL	PY	N	Fe	1	0	M	SS	8
33	3	1.9	1.26	0.86	2.06	2.7	1.31	A	M	M	VL	M	YB	N	Fe	1	4	M	SS	1
34	3	4.2	2.86	1.29	15.50	120	7.76	CK	C	M	L	M	RB	SA	Fe	3	3	M	R	19
35	3	4.37	3.6	1.66	26.12	39.7	1.52	A	C	M	VL	M	YB	CH	GR	3	3	M	R	2
36	3	4.58	4.57	2.52	52.75	70.4	1.33	A	C	M	VL	M	RB	SA	GR	2	3	M	R	4
37	3	4.8	2.87	1.78	24.52	76.2	3.11	A	C	M	VL	M	DG	SA	GR	2	1	M	R	5
38	3	3.8	2.24	1.46	12.43	78.7	6.33	A	C	M	VL	L	BG	SA	Fe	2	3	M	R	10
39	3	2.4	2	1.5	7.20	51	7.08	A	C	M	VL	L	WG	SA	N	4	1	M	R	12
40	3	3.19	2	9.2	58.70	29.5	0.50	A	C	M	VL	H	LG	N	M/	1	2	M	SS	6
41	3	6.28	4.46	4	112.04	113	1.01	A	C	M	VL	M	WY	TU	M/	2	3	M	R	3
42	3	3.15	2.67	2.26	19.01	46.3	2.44	A	C	M	VL	M	WY	TU	M/	3	2	M	R	5
43	3	2.7	2	1.6	8.64	22.6	2.62	A	C	M	VL	L	WG	N	M/	2	1	M	R	12
44	3	1.79	1.53	1.07	2.93	49.2	16.79	A	C	M	VL	H	BG	SA	N	5	4	M	R	45
45	3	2.18	1.58	0.96	3.31	48.6	14.70	A	C	M	VL	H	WG	N	N	4	3	M	R	40

46	4	0.14	0.11	0.021	0.0003	2.4	7421.15	SC	M	M	VL	H	G	N	N	5	1	M	S	1515
47	4	0.5	0.4	0.028	0.01	2.4	428.57	SC	M	M	VL	H	G	N	N	2	1	M	S	1510
48	4	1.07	0.73	0.08	0.06	1.1	17.60	SC	M	M	VL	H	G	N	N	3	1	M	S	25
49	4	1.46	0.95	0.47	0.65	0.1	0.15	SC	M	M	VL	H	G	N	N	4	1	M	S	1
50	5	0.36	0.19	0.009	0.0006	1.1	1786.87	SC	M	M	VL	H	DB	N	N	2	3	M	S	52
51	5	0.42	0.41	0.06	0.01	0.1	9.68	SC	M	M	VL	H	LG	N	N	2	1	M	S	42
52	5	0.73	0.54	0.056	0.02	0.2	9.06	SC	M	M	VL	H	G	N	N	1	1	M	S	7
53	5	0.93	0.82	0.06	0.05	0.3	6.56	SC	M	M	VL	H	G	N	N	1	1	M	S	5
54	5	0.74	0.52	0.04	0.02	0.2	12.99	SC	M	M	VL	H	DB	N	N	2	4	M	S	6
55	6	0.91	0.78	0.65	0.46	0.4	0.87	D	M	M	N	H	DB	N	M/	0	4	M	SS	1
56	6	0.56	0.55	0.53	0.16	<0.1		D	M	M	VL	H	DG	N	M/	0	2	M	S	1
57	6	0.71	0.56	0.43	0.17	0.1	0.58	D	F	M	N	H	WB	N	M/	0	0	M	S	1
58	11	2.13	1.83	0.14	0.55	0.7	1.28	SC	M	M	VL	H	GB	N	M/	3	5	M	SS	1
59	11	2	1.63	0.09	0.29	4.2	14.31	SC	M	M	VL	H	RB	N	M/	2	6	M	S	10
60	11	0.27	0.24	0.041	0.00	12.2	4591.99	SC	M	M	VL	H	DG	N	M/	4	3	M	SL	316
61	11	0.74	0.4	0.04	0.01	12.4	1047.30	SC	M	M	VL	H	DG	N	M/	4	2	M	S	304
62	11	0.7	0.7	0.05	0.02	12	489.80	SC	M	M	VL	H	DG	N	M/	3	3	M	SL	306
63	11	0.72	0.7	0.04	0.02	13	644.84	SC	M	M	VL	H	BG	N	M/	3	5	M	SL	312
64	11	1.1	0.86	0.59	0.56	8	14.33	SC	M	M	VL	H	DG	N	M/	2	2	M	S	132
65	11	1.16	0.82	0.48	0.46	7.4	16.21	SC	M	M	VL	H	BG	N	M/	2	5	M	S	136
66	11	0.17	0.16	0.12	0.0033	<0.1	30.30	D	M	M	VL	H	DG	N	M/	0	2	M	S	1
67	11	0.39	0.37	0.3	0.04	0.4	9.24	D	M	M	VL	H	DG	N	M/	0	2	M	S	6
68	11	3.57	2.9	1.5	15.53	20.5	1.32	A	C	M	VL	M	WB	SA	M/	4	2	M	R	3
69	11	1.45	1.45	0.92	1.93	4.5	2.33	A	M	M	VL	L	BG	N	M/	2	2	M	S	3
70	11	1.4	1.28	0.62	1.11	2.9	2.61	V	M	M	VL	L	GB	N	M/	0	3	M	S	1
71	11	1.57	1.06	0.88	1.46	3.7	2.53	A	M	M	VL	L	WB	SA	M/	3	2	M	R	3
72	14	0.2	0.19	0.19	0.007	0.1	13.85	D	F	M	VL	H	DG	N	M/	0	2	M	SL	3
73	14	0.75	0.68	0.58	0.296	0.8	2.70	D	M	M	VL	H	BG	N	M/	1	3	M	S	4
74	14	0.52	0.51	0.38	0.101	0.2	1.98	D	F	M	VL	H	DG	N	M/	1	1	M	SL	1
75	14	2.42	1.28	0.14	0.434	17.6	40.58	SC	M	M	VL	H	BG	N	N	3	3	M	S	43
76	14	1.19	1.05	0.085	0.106	0.8	7.53	SC	M	M	VL	H	DG	N	N	3	1	M	S	8

77	14	1.06	0.89	0.18	0.170	1	5.89	SC	M	M	VL	H	RB	N	N	2	3	M	S	7
78	14	0.82	0.55	0.033	0.015	0.2	13.44	SC	M	M	VL	H	DG	N	N	3	1	M	S	4
79	14	0.3	0.27	0.029	0.002	<0.1	50.00	SC	M	M	VL	H	RB	N	N	4	4	M	S	1
80	14	0.32	0.26	0.039	0.003	11.5	3531.80	SC	M	M	VL	H	YB	N	N	5	6	M	S	248
81	14	0.34	0.29	0.028	0.003	12.1	4382.79	SC	M	M	VL	H	DG	N	N	4	2	M	S	196
82	14	1.05	0.79	0.16	0.133	10.9	82.20	SC	M	M	VL	H	RB	N	N	3	1	M	S	210
83	14	2.41	1.28	0.14	0.432	20.4	47.24	SC	M	M	VL	H	BY	N	N	4	4	M	S	304
84	14	0.37	0.3	0.09	0.010	9.86	986.99	SC	M	M	VL	H	YB	N	N	5	5	M	S	154
85	14	1.44	1.26	0.9	1.633	5.5	3.37	A	C	M	L	L	WB	SA	M/	2	4	M	R	12
86	14	2	1.56	0.86	2.683	3.7	1.38	ST	F	M	VL	L	WG	TU	M/	3	3	M	R	3
87	15	1.55	1.16	0.22	0.396	2.1	5.31	SC	M	M	VL	H	BY	N	M/	3	4	M	SS	5
88	15	0.3	0.3	0.3	0.027	<0.1	3.70	D	M	M	N	H	BG	N	M/	0	2	M	S	2
89	15	1.37	1.32	0.62	1.121	2.8	2.50	A	C	M	VL	H	RG	SA	M/	3	5	M	R	7
90	15	1.71	1.29	0.9	1.985	3.6	1.81	ST	F	M	VL	H	DG	TU	M/	3	2	M	SS	3
91	15	0.79	0.54	0.16	0.068	4.1	60.07	SC	M	M	VL	H	YB	N	N	2	5	M	S	48
92	15	0.45	0.26	0.019	0.002	4.2	1889.34	SC	M	M	VL	H	BG	N	N	3	4	M	S	52
93	15	0.79	0.72	0.07	0.040	4.8	120.55	SC	M	M	VL	H	DG	N	N	4	2	M	S	13
94	15	1.02	0.82	0.1	0.084	4	47.82	SC	M	M	VL	H	BG	N	M/	2	4	M	S	71
95	15	0.28	0.26	0.04	0.003	3.2	1098.90	SC	M	M	VL	H	YB	N	N	3	5	M	S	80
96	15	0.46	0.3	0.019	0.003	4.6	1754.39	SC	M	M	VL	H	DG	N	N	4	2	M	S	106
97	15	1.13	0.84	0.08	0.076	2.3	30.29	SC	M	M	VL	H	DG	N	N	3	2	M	S	56
98	16	0.84	0.7	0.12	0.071	0.4	5.67	SC	M	M	VL	H	BG	N	N	3	4	M	SS	92
99	16	0.4	0.28	0.02	0.002	0.5	223.21	SC	M	M	VL	H	LG	N	N	5	1	M	SS	90
100	16	0.88	0.34	0.16	0.048	0.38	7.94	SC	M	M	VL	H	YB	N	M/	5	5	M	SS	91
101	16	0.7	0.54	0.06	0.023	0.44	19.40	SC	M	M	VL	H	G	N	N	3	1	M	SS	92
102	16	1.06	0.83	0.18	0.158	0.42	2.65	SC	M	M	VL	H	BY	N	M/	5	4	M	SS	93
103	16	0.33	0.32	0.27	0.029	<0.1	3.45	D	M	M	VL	H	BG	N	M/	0	4	M	SS	2
104	16	1.53	1.22	7.64	14.261	1.7	0.12	A	C	M	VL	M	WG	N	N	3	3	M	R	4
105	16	2.58	2.02	1.68	8.755	6.3	0.72	A	C	M	VL	M	BR	N	M/	2	2	M	R	2
106	16	1.52	1.27	0.75	1.448	6.3	4.35	A	C	M	VL	M	BG	N	M/	1	4	M	R	23