Research into the ferrous metallurgy of Rhodesian Iron Age societies

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SYNOPSIS

Iron-working was a widespread economic activity in Iron Age Rhodesia, and merits historical and metallurgical investigation. However, the research done so far has been incidental and poorly disseminated. This paper reviews the available evidence and the ways in which it can be interpreted by archaeologists and historical metallurgists. Particular attention is paid to smelting techniques and current metallurgical research, and brief suggestions are made for future research.

SAMEVATTING

Die bewerking van yster was 'n wydverspreide ekonomiese bedrywigheid in Rhodesië van die Ystertydperk en regverdig 'n geskiedkundige en metallurgiese ondersoek. Die navorsing wat tot dusver gedoen is, was egter toevallig en swak versprei. Hierdie verhandeling gee 'n oorsig oor die beskikbare getuienis en die maniere waarop dit deur argeoloë en geskiedkundige metallurge vertolk kan word. Daar word veral aandag geskenk aan smelttegnieke en die huidige metallurgiese navorsing, en kortliks voorstelle in verband met toekomstige navorsing gemaak.

INTRODUCTION

'The inhabitants of two small towns of the land of Sofala . . . depend entirely on the iron trade for their livelihood; certainly, a great number of iron-mines are found in the mountains of Sofala'. Indian iron '. . . is not as good as Sofala iron which excels in its quantity, quality and malleability'. Thus speaks El Idrisi in his 'Geography' of 1154 A.D., one of a number of medieval Arab writers who mention the iron trade of the East African coast[1]. This hinterland of Sofala has usually been equated with Rhodesia, but, as Summers[2] has pointed out, there is little in the form of large slag heaps (such as those at Meroe, in the Sudan[3]) to encourage this idea. It is doubtful whether the size of furnace known to have been used in Rhodesia could have produced for an export market. Notwithstanding these facts, the question must remain open, for there are clear indications in the form of large numbers of furnace remains and very extensive quarrying operations that the area between the Zambezi and the Limpopo has at some time carried a very considerable iron industry.

It is the purpose of this paper to discuss the metallurgical and archaeological aspects of this iron industry. The archaeological and ethnographic evidence is great but largely under-investigated, and its interpretation is fraught with difficulties. Proper consideration of this varied evidence will yield important information on the place of Rhodesia in sub-Saharan historical metallurgy, on the use of this evidence as a tool in interpretative archaeology, and on the role of the iron-worker in Rhodesian Iron Age societies.

Ideally, iron-working in Iron Age societies known to have mined and worked other metals should be discussed as part of a general industrial phenomenon. However, in this paper little reference will be made to copper and gold mining in Rhodesia, which have been very adequately treated elsewhere[2]. On the other hand, archaeological evidence relating to copper and gold metallurgy is sparse, partly because modern mining activities have necessarily destroyed much of it. The finds at Sinoia Caves[5], and perhaps Naba and Chicago farm[4], stand alone as satisfactory evidence of copper smelting, although the analysis, and distribution studies, of copper cross ingots will one day give useful insights into trade and copper-smelting techniques. The gold-smelting furnaces reported at Zimbabwe were poorly recorded[6], and the great bulk of gold objects found there and at other ruin sites have been dispersed or lost. Furthermore, very few ethnographic references to non-ferrous mining and metallurgy exist, and this lack of material frustrates any study of the relationship between ferrous and non-ferrous industries in Rhodesia. It may be worth mentioning that current archaeological opinion regards copper-, gold-, and iron-working groups as separate but essentially complementary, each utilizing the economic possibilities provided by their local ores. However there is a very close geochemical association between iron and gold in some Rhodesian iron ore deposits, which suggests both a connection between ferrous and auriferous metal workers in the Iron Age, and, incidentally, the possibility that a few of Summers' gold mines may be iron mines. However, this whole proposition is tentative and needs closer study.

BRIEF SKETCH OF PAST RESEARCH

Archaeologists, ethnographers, and metallurgists have paid little attention to iron-working in Rhodesia. Observers have at various times recorded what they saw[7–11], or what they heard[12, 13], but no one, except perhaps Stanley[9, 14] and Davidson[15], has made any aspect the subject of intensive or professional investigation. This has had two regrettable results. Firstly, features of interest both to the archaeologist and metallurgist have often been overlooked or misinterpreted, and, secondly, there has been a tendency to follow the views of an earlier school of archaeologists and anthropologists who regarded iron smelting as an economic ritual controlled by the need

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for secrecy, sexual taboo, and general exotic mystery[16, 17]. Walter Cline's classic study[18] of mining and metallurgy in Africa dismisses Rhodesia in a couple of lines. Although various archaeologists have touched on the subject as it affected their own research interests[2], it remained a backwater until recent influences from Britain and South Africa generated interest in the application of scientific techniques to the elucidation of this problem. Rhodesia's place in this new research field is exemplified by the large-scale investigation[19] in 1972, sponsored by the South African Government, of a Rhodesian iron-working group.

THE NATURE OF THE EVIDENCE

Apart from the historical sources referred to above, the evidence available is of two main kinds, archaeological and ethnographic.

Iron-smelting furnaces, slag heaps, and tuyères are common surface finds, both on European farms and in Tribal Trust Lands, especially in those parts of the country that have supported a large population. These finds can occasionally be related to cultures and periods, but are generally undatable, although their very survival implies a nineteenth century date for the furnaces. A few of these furnace finds have been recorded in fair detail[20–23], while others have received only a bare mention[24–27].

Slags and tuyères are very common in excavations[28–35], but very few furnaces have been found on Iron Age sites[4, 33, 36, 37], and the dating of those that have been found is often debatable. Less commonly found on the surface and in excavations are iron ores and iron objects; the generally acid soils of Rhodesia do not favour the preservation of iron. With the important exception of Zimbabwe[6, 38] and a few other Rhodesian ruins, iron finds are usually slight and fragmentary. The occurrence of an iron-rich mineral in a context clearly indicating its use as a smelting ore is rare, but this is to be expected because most of the ore collected for smelting would have been used. Furthermore, most excavators have not considered ore finds from a metallurgical angle, and have usually discarded or failed to record them.

The possibilities of ethnographic study of Rhodesian iron-working have naturally been dwindling progressively since the advent of accelerated social change in the late nineteenth century. The only group known to have retained detailed knowledge and the necessary practical skill are the Njanja of Charter District. As they have apparently been stimulated by the policy of successive District Commissioners, this retention is to some extent artificial. The skills of one family of the Njanja have been the subject of a number of public demonstrations and published articles since 1917[7–10, 27]. It is likely that the last demonstration (in 1972) will be the only properly recorded one, even though their retained skill was then insufficient to produce a satisfactory bloom[19].

However, in the Tribal Trust Lands, especially those farthest from the towns, there is still a considerable number of old men who, if they did not themselves actually smelt iron, certainly helped in, or at least observed, the operations of others. Their knowledge of the subject ranges from hearsay to detailed descriptions and to a claimed ability to smelt iron and a willingness to do so. It is probable that few of them will actually be able to produce iron satisfactorily, but these tribesmen remain a vital source of information, especially as it is ultimately the ironworker himself who is best able to tell us not only *what* he did but *why* he did it.

A different source of ethnographic information is the writing of early European travellers and antiquaries, especially Richard Hall[6, 39] and J. Theodore Bent[11], who recorded centres of mining and iron-working, and made their own sketchy observations of furnaces and techniques.

HISTORICAL METALLURGY

Iron Ores

The factor that exercises the greatest control over extractive methods is the character of the ore. In 1937, Cline[18] recognized the limits placed on research by the lack of detailed information on this point. Success in smelting depends on the extent to which the smelter masters the peculiarities of his ore, and discrimination in the selection of ores is one of the first points the historical metallurgist can usefully consider. The major sources of iron ore used in Rhodesia by Iron Age peoples can be listed, but there are almost certainly many minor sources of ore that have been forgotten in the tribal areas or that have left few visual remains. Since tribal informants can rarely pinpoint the exact location of the sources, the metallurgical properties of some of these cannot be assessed. Hence only those sources that can be tied in with a definite geological formation are listed.

Most major sources of ore appear to be associated with banded ferruginous quartzites and banded ironstones. These are found in all the schist belts of the Rhodesian Primitive Systems. They are usually identifiable as long low hills, which are widespread over much of the country. Generally, the total iron content of these alternating bands of hematite, magnetite, and chert varies from 15 to 50 per cent. Higher-grade magnetite and hematite occur locally, and it is these latter deposits that are exploited industrially today. These banded iron-rich rocks were mined in pre-European times at Makaha[40], Arcturus[27], Manesi[2, 4], Mount Wedza[2, 7, 9, 19, 39, 41, 42], Que Que [41, 43], Umvuma[41, 42], Selukwe [26, 41, 42, 44], Mulungwane[2, 45], Thabas Inyorka[2, 45], Filabusi[46], Buhwa[4], and in localities near Gwanda[47, 48]. All these quarries were in magnetite or hematite deposits, but the actual grade is not always clear from the accounts. The only iron ores other than those from banded ironstone deposits known to have been used are the magnetite carbonatites of the rare alkali ring complex at Dorowa near Buhera[2], dolerite decomposition products on Mount Anwa[2, 11], near Macheke, a manganiferous iron ore in Gutu district[24], and ferricrete, a surface deposit, mentioned by Manyubi smelters[13].

The factors affecting the choice

of ore may have been varied and often non-metallurgical. Political considerations must have often affected the availability of ore, and the final choice was probably the result of a fine balance between the ore's metallurgical properties, its availability, and the distances over which the bloom or the ore had to be carried back to the demand source.

As far as metallurgical considerations are concerned, selection must have depended on the ore's reduction characteristics. It should be mentioned here that the fame of an ore source may have been widespread. In the case of Mount Wedza, oral evidence shows that the ore was prized by smelters from Charter, Chibi, Selukwe[42], and Mtoko. High-grade ores are usually preferred by primitive smelters because these, if successfully smelted, give higher yields and less slag[49]. Lower-grade ores are also acceptable if they can be upgraded by beneficiation. Hematite, which averages up to 90 per cent iron oxides, is usually the highest grade of ore used, but it is massive, not easily crushed, and of low permeability. Tylecote[50] has shown that this ore behaves unsatisfactorily in primitive low-shaft furnaces. At a demonstration in Selukwe in 1972, tribal iron-smelters were quite unable to reduce high-grade Buhwa hematite[42]. But it is clear from the evidence of geologists that hematite was commonly mined by pre-European smelters, and it has been found on Iron Age sites, in contexts suggesting smelting activities, near Buhwa[4], and Coronation Park[31]. The Manyubi of the Matopos stated their preference for high-grade hematite over ferricrete, which was 'very hard work'[13]. However, there are no indications of the state in which the ore was charged.

Preliminary roasting would make the ore less impermeable and hence more reducible, but there is no evidence of this. The size of the ore as charged would also be important. In an experimental low-shaft furnace[50], a British hematite of pea size gave very low yields, but the yield improved when the ore was finely ground. The problem of how primitive Rhodesian iron-smelters made use of the local hematite is difficult to solve on the available evidence.

The use of Wedza ore by the Njanja in 1972 is a good example of the upgrading or beneficiation of a relatively poor ore. The banded ironstone of Wedza Mountain is particularly fissile, and is mined where the beds are least contorted and fissility is at a maximum. The siliceous bands are split off by hand, a practice paralleled in the Selukwe area[44]. By these means, the non-ferruginous content is reduced to less than 30 per cent. The magnetite bands are highly permeable, and the ore is rendered more so by a degree of pre-roast as it travels down the furnace into the reduction zone. The Arcturus ore mentioned above was probably also easily reduced because it crumbled naturally. Again, the Arcturus ore had very definite self-slagging properties; all its MnO (3 to 12 per cent) would have replaced FeO in the slag, thus promoting higher yields.

The mining of localized deposits of limonite is reported from Thabas Inyorka[45]. This oxide is usually impure and of low grade, but this disadvantage may have been outweighed by its occurrence in powdery, and thus reducible, form.

Smelting Techniques

Until fairly recently, little was known of the techniques of iron smelting employed by Iron Age groups in Rhodesia. The data recorded by early travellers and by observers of public demonstrations by the Njanja were sparse and unsatisfactory. Walter Cline's bibliographical study of African metallurgy stopped at the Zambezi, largely through lack of relevant literature south of it. This position has to some extent been improved by a major study[19] of the Njanja iron-workers, and by a smaller investigation[42] of remanent skills in Selukwe. Both these studies approached the problem from a metallurgical point of view. Less detailed, but still important, oral evidence has been obtained in the Matopos[12, 13], but it must be said that informants who are not actually demonstrating their work are rarely able to give precise details of practices, even if they are remembered. Because extant furnaces on the surface or in archaeological levels have not been investigated with metallurgical considerations in mind, much potentially useful information has been lost.

Types of Furnace

The most obvious expression of technique and the one most amenable to investigation is furnace type. Almost all the furnaces from archaeological and ethnographic contexts in Rhodesia fall into one easily defined category, and it is felt that this classic Rhodesian type was the rule throughout most of the Iron Age period. It is in contrast to the multiplicity of types found in South[51] and Central Africa[18].

The main fabric of these Rhodesian furnaces is of clay and consists of a hood covering a fire-place to conserve heat. In the top of this cover is a charge-hole. At the front of the furnace is a large opening through which the initial fuelling is made, the tuyères arranged, and the bloom withdrawn after smelting. Usually opposite this are from two to six smaller holes through which the tuyères are passed. The mean height of these furnaces is 3 feet from the top charge-hole to the base of the fire-bed, which averages 4 square feet. The blast was provided by bag bellows, usually of goat skin. The best technical description of the operation of this general type of furnace is given by Tylecote and his co-workers[50]. Rhodesian examples have been described by Bent[11], Bernhard[21, 22], Cooke[13, 20], Robinson[23], Franklin[7], Stanley[9], Goodall[10], Posselt[8], Garlake[33], Hatton[12], and Weischoff[24], while one has recently been found in an early Iron Age context in the Mazoe District[4].

Variations from this pattern are not great, and few can have any metallurgical significance. Within this category, size variation is probably a function merely of production capacity but is, in any case, slight.

Some furnaces possess side furniture such as 'wings' of clay or granite slabs, for instance Ziwa B-Type[21], Toghwana Dam (Matopos)[20], Bent's furnace[11], and Hatton's furnace[12]. These probably served as shields to protect the bellows operators from the intense heat emanating from the front

opening. This is particularly evident from the position of the wings in relation to the presumed bellows position in Ziwa B-Type.

The side furniture employed by the Njanja at various times is varied[7–10, 19, 23]. From photographs of demonstrations, a circular area about 2 feet wide is often included delineated by a low clay wall. This was used as a floor for final preparation of the ore[10]. On either side there was often a solid platform of moulded clay about 6 inches high, occasionally with a slight depression on the upper aspect. This served as a step to maintain the balance of the operator while charging and observing through the charge hole, and as a charge measure, for the depression holds about a cupped handful of beneficiated ore.

'Sumps' or 'funnels', often sunk up to 2 feet below the level of the fire-bed, are a common feature in Inyanga[21, 36], but examples also occur in Urungwe[33], Chibi[23], and near Khami[37] in a rare open-bowl furnace. These have usually been interpreted as receptacles for molten iron[23]. This is improbable, as temperatures sufficient to melt iron are unlikely to have been attained under normal conditions in this type of furnace. A more probable explanation is to be found in the common use of a charm placed in the furnace to ensure success. This practice was mentioned by Hatton's informant in the Matopos[12], and by the Njanja[19], and is well known elsewhere in Africa[52, 53]. At Leaping Waters Farm[36], the 'sump' was found to be full of charcoal, but the non-circulation of air certainly precludes any metallurgical function. Incidentally, the presence and absence of these 'sumps' in furnaces in Chibi and Inyanga has been suggested as evidence of movements of people and techniques[23].

Metallurgical Incidents

Variant features for which a metallurgical explanation is certain are the number and height of the tuyère holes above the floor level. The majority of Rhodesian furnaces have two tuyère holes, and were thus blown by two pairs of bellows. However, Robinson's Chibi furnaces[23] each had one tuyère, as did both recorded Matopos furnaces[12, 20], and perhaps Inyanga Site IX[36]. On the other hand, three to four are reported from Gutu[24], while Brown[25] reports up to six. The whole question of the metallurgical significance of tuyère number is problematic. It is possible that single tuyères indicate forging furnaces, which would not require the degree of control over air supply normally necessary for successful ore smelting. Yet, such single-tuyère furnaces may have smelted ores that required less control in the smelting. The two tuyères of Ziwa B-Type entered at opposite sides[21]. This is an uncommon feature, and is particularly interesting in an area where furnaces of 'classic' type are found. Bernhard makes the valid point that a change of smelting technique is indicated.

A feature with a definite metallurgical function and one, which being low down, is more frequently preserved, is the height of the tuyère hole above the fire-bed. The gap between the tuyère and this floor is filled with charcoal. This largely inert charcoal bed acts partly as a heat insulator and as a gas-flow channel. The bloom forms in it just below the tuyère end[50, 54]. It absorbs fines from the charge, thus helping to avoid a back pressure. The least viscous fraction of the slag collects in this bed and thus slag-metal separation is promoted. The depth of the bed is critical. Controlling factors vary, but include the angle of the tuyères, about which little is known, the ore type, and the ratio of fuel to ore. In 1972, the Njanja provided a bed depth of 10 cm or less by laying the tuyères on the ground and scraping a slight depression beneath them[19].

To judge from photographs of earlier Njanja demonstrations, they used greater bed depths in the past[7–9, 23]. Indeed, published scale drawings show that bed depths are almost always greater than this. In the case of Ziwa A-Type[21] and Cookes' Matopos furnace[20], the required bed depth was achieved by building the furnace on a slope and putting the tuyère hole on the higher side, or by building up a blowing platform to the rear.

While there may be some evidence of changes or variations in technique, these must have been minimal and have fallen within a general range of the basic principles described by Tylecote[50], Hatton[12], Posselt[8], Franklin[7], and Stanley[9].

What is at once apparent is that this classic Rhodesian type of furnace stands in complete contrast to the type used after about 1600 A.D. in northern Zambia, Malawi, Tanzania, and the Congo[18]. Classic Rhodesian furnaces are small and squat, and the blast is provided by forced draught. The northern furnaces are blown by induced draught, using the principle of convection[18], which partly explains why they are usually tall and conical. These major distinguishing features have been recognized and commented on by Cline[18], Phillipson[53], Sassoon[55], Fagan[56], and Chaplin[52]. Cline makes the point that the geographical distribution of induced-draught furnaces coincides with those areas known to have been limbs of extensive trade networks. These furnaces are well adapted to large-scale trade in iron by their capacity, and perhaps by the quality of the resultant material[57]. Induced-draught furnaces, and indeed any furnaces of similar size, are not known to have been used south of the Zambezi. It is clear that these revolutionary techniques of iron production brought to northern Zambia by the Bisa-Lunda migrations never reached Rhodesia[57, 58]. In this respect, Rhodesian techniques lagged behind those further north[57]. The distribution of 'small clay furnaces less than three feet overall seems scattered and without significance'[18], although this type may represent a relic of an earlier stage in African metallurgy. A further important point concerns the relation between this classic Rhodesian type, on the one hand, and the variety of types to the north and south on the other. In the case of the Venda of the northern Transvaal, there are good ethnographic reasons for presuming a Rhodesian origin, but the peculiar furnace structure they used prevents facile connections with Rhodesian iron-working. This is one problem that can best be elucidated by excavations in Rhodesia.

A remnant of a still earlier technique in Rhodesia is suggested by isolated occurrences of the small open-bowl variety. Robinson excavated two such furnaces near Khami Ruins[37], and the operation of such a furnace was unsuccessfully demonstrated by a tribesman from Nyashanu near Buhera[42]. This variety functioned under conditions of great thermal inefficiency, and probably represents the original type of furnace used in Africa when smelting of only the least refractory ores was attempted. Its occurrence was widespread in Africa, examples having been found in Egypt[59], the Sudan[60], Kenya[61], certain parts of Angola and Congo[18], and Zululand, Swaziland, and Botswana[62].

Attempts have occasionally been made to read a metallurgical explanation into the siting and orientation of furnaces. Some writers suggest that shelter from the wind was important[20], others that exposure was desirable[36]. In fact, a wide variety of factors probably influenced the choice of site. The direction and velocity of the wind do not affect the success of smelting in any way, because, if shelter from the wind is required by the operators, they erect a windbreak[11]. Shelter is certainly needed from the weather, and smelting may have been carried out at night as was the practice of the Njanja in former times, or in an open-sided hut[19].

Smelting Procedures

The most detailed account of the methods used by one Rhodesian group working with a forced-draught furnace is Küsel's study of the family of Headman Ranga in Charter in 1972[19]. Until the results of this appear, information about the techniques used can be derived only from archaeology and from the rather inadequate published accounts mentioned above. But these give little indication of metallurgically significant practices and how these varied with the ore used or with the cultural affinities of the smelters. In particular, there are no data on fuel-ore ratios. For a given ore this would indicate expected yields and the carbon content of the bloom[50]. Again, almost nothing is known of the methods of charging and the control of the blast. At best, there is a little incidental information on the use of a flux, slag-metal separation, and the possible accidental production of cast iron.

Fluxes

It is generally true that the use of a flux in the small shaft furnaces used by primitive smelters is unnecessary[49]. The iron oxide content of the high-grade ores normally smelted is high enough to promote self-fluxing of the low silica content. Sufficient ferrous iron combines with the total silica to form a fayalite-type of slag, which is easily dealt with at the normal operating temperatures of about 1200 °C. Any slag entrapped in the bloom can be adequately removed by subsequent hammering. It has been pointed out that the addition of CaO, the most common flux, is critical[63]. If the CaO addition is more than 15 per cent, the melting point of the slag is increased and slag-metal separation is reduced. The rate of absorption is slow, even at high temperatures. At the optimum of 12 per cent lime, the reduction in melting point will be slight—not more than 50 °C. It is not surprising, therefore, that iron smelters in Rhodesia did not generally add a flux of any sort to the charge.

However, it seems that fluxing practice was known. The Manyubi retained smelting slag for use as a flux in their forging furnace[12]. More significantly, Summers found a mass of burned bone near his smelting site (XXVIIID) in Inyanga[36]. Bone is rich in calcium, and its use as a flux is recorded among the WaFipa in Tanzania[18] and the Venda in South Africa[51]. It is likely that this evidence will be supplemented by analyses of slags. In Rhodesia, at least one large piece of Early Iron Age slag has been found containing pieces of shell. Shells are lime-rich and are known to have been added as a flux by smelters in Malabar, India[49].

Slag-Metal Separation

The separation of the slag from the metal is highly desirable as this results in a more easily forged bloom and a purer iron. The principle of separation in this type of furnace depends on the liquid slag moving down from the iron bloom, which remains solid above[50, 54]. If the expected volume of slag is great and cannot be contained in the furnace without impeding slag-metal separation, the slag can be tapped out of the furnace[49]. For a very liquid slag, this practice prevents blocking of the tuyères.

In Rhodesia, there is no ethnographic evidence for the tapping of slag. Furnaces of small capacity, using ores low in gangue, such as the majority of Rhodesian furnaces, produce quantities of slag generally small enough to be contained in the furnace without clogging the smelt or blocking the tuyères. In the 1972 Njanja demonstration[19], the slag volume from the second smelt was small. Much of it had a relatively high melting point (between 1400 and 1500 °C) and was fairly viscous. The least viscous fraction collected in the small charcoal bed to form a porous, light-green slag, and a darker and denser fraction trickled out through the furnace door in small, highly viscous fingers. In the first smelt, the slag tended to block the tuyères, necessitating much vigorous punching with iron rods, which broke the tuyères and brought the smelt to a premature end. The fault here may have been the shallow depth of charcoal bed. Whether the reduced need to tap the slag (shown here) and, indeed, the inability to do so (shown by the high viscosity of the slag) is paralleled in other smelting methods in Rhodesia will depend on the nature of the ore and the fuel-ore ratio. The common large frontal openings would have allowed natural tapping, and this would have been facilitated by the sloping furnace floor in Ziwa A-Type[21]. The physical evidence provided by slags from excavated sites indicates that, while liquid slags were common, few of these were actually tapped.

Cast Iron

The creation in primitive furnaces of conditions suitable for the melting of iron is a rare occurrence. But ethnographic references to the casting of iron are persistent, and the whole question is interesting and controversial. It is at once clear that Iron Age smelters, producing for an unsophisticated market, preferred to make wrought iron, which is easy

to work. Cast iron can neither take nor keep an edge, and shatters with violent use, but no primitive furnace could normally attain the high temperatures required to liquefy iron[49, 63].

However, references to the flowing of iron into moulds are too frequent to be ignored. Many instances have been recorded north of the Zambezi[18], and similar reports come from Natal and South West Africa[62]. In Rhodesia, an informant has stated that iron could be made to flow 'like water into a picture in the soil'[42]. Experience in techniques of ethnographic interviewing indicate certain possible objections[42]. Firstly, some informants may be referring to copper, which was cast as standard practice in Iron Age metallurgy, although the Rhodesian source was adamant that he was talking about the material 'from which we make hoes'. In any case, it is unlikely that he had ever witnessed copper smelting by traditional methods. Secondly, these statements may be the result of background interference. Many of these old men have at one time worked in small European mines and may have seen modern methods of gold or copper casting, and thus been influenced in their evidence. Yet this cannot account for all these puzzling references.

The melting of iron in primitive furnaces is theoretically not impossible under the right conditions. Cline[18] mentions instances where the melting of the iron had specifically to be avoided. Metallographic work on primitive irons in Southern Africa has shown that such freak conditions have occasionally been created[9], while cast iron has been produced in an experimental Roman furnace in Britain[50]. The conditions that must operate before iron will melt in these furnaces must include a highly reducible ore, a high fuel-ore ratio, a maximum temperature, and a reducing atmosphere.

Metallurgical Analysis

The foregoing account is not an exhaustive discussion of primitive iron smelting in Rhodesia. There is no doubt that, with the steady decline in the number of tribesmen who have knowledge of the methods used by their forefathers, much future information will have to come from physical and chemical investigations of ores, slags, blooms, and finished products. Of these, slag is to the historical metallurgist what pottery is to the conventional archaeologist. Its ubiquity, its survival qualities, and the range of information that it can reveal make it an ideal research tool. Normally, an ore and its smelting products are best considered as one incident, but it is rare that an ore, its slag, and bloom will be found so associated as to suggest one smelt or even one smelting tradition at a site.

There are certain major difficulties in the interpretation of this kind of evidence. A question has been asked in the field of copper-bronze historical metallurgy that is most relevant in this context . . . 'How uniform were the extractive techniques and how standardised a product was achieved?'[64]. Stanley[9] has said, on the basis of his metallographic work,' . . . it is evidently a somewhat haphazard proceeding and the products are naturally variable in character'. More recently, African metallurgy has been labelled as 'highly experimental and innovative'[65]. There are no indications, on the evidence available, to suggest the extent to which primitive smelters were able to reproduce results consistently with one ore and in one type of furnace. It has not been possible to observe one group carry out a series of smelts over a period long enough to assess this. The difficulties attendant on this unknown factor are great in the interpretation of isolated slag finds. Unless slag is found in large heaps, as at Meroe in the Sudan[3], or Phalaborwa in the northern Transvaal[66], or in scattered abundance as at Kapwirimbwe near Lusaka[67], there is no guarantee of the representativeness of the total slags produced by the smelt, or the series of smelts from which it came. Again, survival and recovery of slags is random and rarely presents a true picture of the characteristics of the group; some may be true tap slags, others charcoal-bed slags, or merely slagged but unreduced ore, or slags from near the tuyère high in FeO and Fe_3O_4. Indeed, doubts have been expressed on whether such analyses can give any useful information at all. However, what is needed is a very large and comprehensive series of analyses of ores, slags, blooms, and finished products from all over the small shaft furnace area. Only after statistical treatment of these in relation to the pitfalls and the influence of ore type and smelt characteristics can the range of variations be assessed and meaningful deductions be made. Moreover, if it is eventually concluded that methods were standardized over wide areas throughout the Iron Age, this would in itself be significant and worth while.

Again, in broader terms, on what level should interpretations be made? A convenient and relatively safe standpoint is to view pre-industrial metallurgical phenomena in terms of efficiency. But it should be borne in mind that Iron Age smelters producing for a local market were unlikely to regard their work in terms of such a concept. ChiShona, the language of most Rhodesian Bantu, has no word to convey the idea of most and best for least effort. Iron Age economic conditions were not conducive to efficiency. A smelter is likely to have accepted the yields he obtained, and to have been satisfied with a tool that performed its designed function well. The *mhizha*, or skilled operative, in Shona society was judged by the quality of the tools he produced in the forge, not by his mastery of the details of the smelting process, of which neither he nor his customers had any comprehension.

Rhodesian ores and smelting products have received little attention from archaeologists and historical metallurgists. Occasional analyses have appeared, but these have either been partial[68] (that is, quantitative determinations of iron and silica) or merely elemental[33, 34]. These are of little interpretative value. In this respect, Rhodesia lags far behind South Africa, where slags from Mapungubwe were analysed as far back as 1935[69].

This position is changing. A series of approximately one hundred samples is at present being investigated. Most of these are slags, the remainder being ores and cinders. The series comes from about fifteen dated Iron Age sites and from one

undated hill site near Wedza Mountain. The work is proceeding broadly according to guidelines suggested by pioneer investigations of pre-industrial slags in Britain[70, 71], and by recent work in South Africa[51]. Identification of mineral phases, and their arrangement, by reflected light microscopy has already been completed and is supported by a full photomicrographic record. Minor confirmatory work by transmitted light microscopy, X-ray diffraction, and electron microprobe techniques is under way. Full chemical analysis of the least oxidized and leached material has recently been begun, together with partial analysis of the remainder.

Certain expected difficulties in treatment have already been encountered. The samples as received were in very variable physical condition, having been subjected to different soil and weathering environments. Because these have probably had little effect on observable microstructures, the spatial occurrence of free ferrous iron as wustite is unchanged, although some of it has been oxidized to magnetite. Leaching has probably removed much alkaline material, and the laboratory analysis will not always truly reflect the 'tap' analysis or the analysis at the end of the smelt. It has been shown how the 'tap' analysis can be calculated, taking into account certain basic assumptions applicable to pre-industrial slags[70]. These problems have a bearing on assessments of furnace operating temperatures. Since oxidation and the loss of alkaline material will raise the slag melting point, there is little point in measuring this with the hot-stage microscope or by differential thermal analysis. A more reliable method for the determination of furnace operating temperatures is based on thermodynamic data derived from the calculated 'tap' analysis and on the relevant phase diagrams[70, 71].

The purpose of this research can be stated simply. It is hoped to investigate the range of characteristics displayed by primitive Rhodesian smelting slags, and how these relate to their mother ores and to one another, and to gain specific metallurgical information. This includes the type of ore used, and selection and discrimination in the use of ores; the fuel-ore ratio; the use of a flux, if any; the working temperature of the furnace; the 'tapability' of the slag; and, the amount of FeO unnecessarily left in the slag. A minor aim is to assess relative levels of efficiency against a background of time and culture, although it is too early to say whether the material will support this type of investigation.

The work has reached a stage where certain general impressions have been gained. The possible use of a shell flux has been discussed above, and more information on the amount of iron left in the slag has been gathered.

In many samples, this iron appears, at high magnification, as small globules of free iron, but it occurs more usually as free FeO or wustite. The bloomery process is an inherently inefficient one as the silicious material must be slagged with twice its weight of FeO to form fayalite ($2FeO.SiO_2$). This leaves less oxide available for actual reduction into iron. This general picture may be modified by the use of a flux or a manganese-rich ore, in which case the silica will take up lime or manganese preferentially to form a slag, thus releasing more FeO. Apart from these, a smelt can be assessed as more or less efficient by the amount of FeO left in the slag over and above that needed to slag the total silica[71]. This will be shown both in the chemical analysis and under the microscope. On this basis the slags investigated have a total iron content of from 20 to 80 per cent, with an average of around 60 per cent. The majority show excess FeO as dendritic structures of magnetite-wustite. This varies from fine, and restricted to the minority anorthite glass phase, to pronounced and independent of the matrix. There is not so far any indication of any variation with time.

Some of the slags investigated were dark and dense, and had a well-defined flow structure. These may have been true tap slags. But the bulk, while clearly having melted, show no signs of having run or of tapping. Many were mixed with charcoal and were probably from the charcoal bed. In microsection the majority exhibited a well-defined crystal structure, indicative of slow cooling (probably within the furnace), and cooling boundaries of magnetite, which suggests a fairly viscous slag behaving in a way reminiscent of pillow lavas. The generally high free FeO content may argue for a low softening point, low viscosity, and easy slag-metal separation if not actual tapping.

Finally, there are certain minor constituent mineral phases that have not yet been identified and that do not fall within the normal range of fayalite, anorthite, and wustite. These may reflect the use of certain ores, of flux, or of particular conditions in the furnace[71].

No analyses have yet been made of Rhodesian crude blooms. These are rare finds, and relatively sophisticated equipment is required to overcome the analytical errors resulting from slag inclusions[50]. Ideally, a bloom should be analysed quantitatively for carbon, phosphorus, and sulphur. The carbon content of the bloom may vary locally according to the presence of entrapped charcoal, but it should be possible to obtain an average. Phosphorus and sulphur will normally be more evenly distributed. To produce good irons, which are low in these elements, use may be made of an ore that does not contain them, or an ore rich in these elements may be roasted prior to charging. Alternatively, or combined with these, the charge may be so worked as to achieve low partition coefficients.

In addition, a bloom can usefully be examined metallographically to determine the extent of slag inclusions, and to support the findings of the chemical work.

Forging Techniques

The factors affecting forging techniques are few compared with those controlling methods of smelting, and were probably standardized over wide areas in the Iron Age. An iron bloom ready for forging contains varying amounts of entrapped slag, carbon, phosphorus, and sulphur. As much of the slag as possible would be expelled by hot hammering, and further hot hammering would serve to raise or lower the carbon

levels on the surfaces of the iron according to whether or not the object was heated in a covering of charcoal. After this, the cutting edges would probably be hardened locally by continued careful forging of these in the forge-fire, and by tempering. Beyond this, the range of techniques known to the Iron Age smith were limited.

What interests the historical metallurgist most are obviously the methods of carburization (or what Coghlan[72] has called the 'role of carbon' in primitive ferrous metallurgy), and of tempering used to produce steels of various kinds, and the more specialized processes such as welding. On all these matters Rhodesian evidence falls short, although VaRanga gave some valuable information in Charter District in 1972[19].

The equipment known to have been used was simple. The Njanja[19] and the Manyubi[12] used a small open fireplace, blown with one tuyère, with a clay or rock shield to protect the bellows operator from the heat. Closed forges are known from Mtoko and Inyanga, Site X[36]. Anvils and hammers of stone were used, probably for the rough work, and of iron for the finer work.

Forge sites are not common in archaeological excavations or on the surface, owing to their slight construction. Apart from the Inyanga site, an area of fire-hardened daga, with some anvils, stone hammers, and much slag, has been found in Urungwe[33]. There have been no reports of hammer scale.

One of the smiths at the Njanja demonstration in Salisbury in 1944 possessed an iron hammer 'which had been in the family for generations', although forge hammers had formerly been 'round, hard stones'. Such iron hammers consisted of 'a flat piece about four to five inches long and one and a half to two inches thick, with a hole punched in the centre for a handle'[7]. At the same demonstration, the smith used, as an anvil for the finer work, a narrow iron spike driven into a baulk of wood. Cline[18] believed this form of anvil was confined to South West Africa, the Congo, and West Africa.

Chemical and metallographic investigations may throw some light on the methods by which a bloom was worked up into a tool. The analytical difficulties mentioned above operate here as well, since the slag inclusions would never be entirely removed. The percentage of phosphorus and sulphur in the iron is controlled by the smelt conditions and is little altered by subsequent forging. The carbon content of a finished tool may vary locally, not only as a result of its preforged state, but also as a result of intentional carburization on cutting edges designed to achieve steely characteristics. The cutting edges merit close investigation, but chemical analysis of so small an area is naturally difficult.

The extent of localized carburization, and the nature and extent of heat treatment on cutting edges, is best observed under the reflected light microscope. This can be supported by Vickers microhardness tests. Such a metallographic approach would also reveal the ways in which a composite article was built up, for example, by fagotting and welding.

The great need for this type of work was voiced by Stanley forty-five years ago[9, 14]. His work, together with that of Davidson[15], on primitive irons in Southern Africa, which included much Rhodesian material, forms useful preliminary metallographic research. They emphasized the non-uniformity of structures, both in the variety of steels and wrought iron, and in the degree of slag entrapment. Nothing seems to have been done since then on Rhodesian iron tools and weapons, and here useful studies could be made in the future.

ARCHAEOLOGICAL INTERPRETATIONS OF IRON AGE FERROUS METALLURGY

When analysing metallurgical evidence, archaeologists have tended to rely on too narrow a range of possible interpretations. A recent collation of modern ethnographic evidence has shown that the ways in which primitive metal-working is organized are varied and admit of few generalizations[73]. This is particularly true in parts of the world subject to a variety of local economic pressures. As an example, one region may carry several communities including one that, possessing no ore resources of its own and being denied access to those of others, has to depend on trade for its iron; another that makes use of a local abundance of raw materials, technical skills, and external demand to build up an export industry; and yet another that merely produces for its own needs. There may be infinite modifications of this pattern. For instance, trade in iron may be in the form of ore, crude bloom, or finished tools, and the metallurgical skills of the importers will therefore be non-existent or vary from an ability to smelt ore to an ability merely to reforge old implements.

It may confidently be expected that there was a similarly infinite variety in metal-working organization in the Rhodesian Iron Age. Today much of the evidence has probably been lost, but sufficient remains of all kinds to show that economic relations in Rhodesian iron-working were neither simple nor static.

Although it is not easy to determine the period of time over which different ore sources were used, when the evidence is reviewed as a whole, it is clear that iron ore was mined on a very large scale. It is tempting to see the populations around Wedza Mountain, Mulungwane, Thabas Inyorka, and Chibi engaged, at least in the nineteenth century, in extensive iron-working and supplying less favoured regions. Theodore Bent[11], in 1893, labelled as an 'Iron Smelting District' on his map the area between Wedza and Fort Charter, '. . . entirely given up to the smelting business, and outside the kraals usually are two or more furnaces', although Hall[39] later believed that the activity was confined to kraals far apart. Bent referred to what he saw in Chibi as '. . . a great industry . . . Here whole villages devote their time and energies to it, tilling no land and keeping no cattle'. For his part, Hall[6] was struck by the '. . . ancient iron-workings extending in an unbroken line for at least twenty miles' in what is now

Belingwe District. He described the Mundie and other nearby ruins as '. . . the Birmingham, Walsall and Wednesbury of the ancients in Rhodesia'. Indeed Hall may have been correct in his assertion that this whole area had been the '. . . chief iron producing centre in Rhodesia, both of the ancients and subsequent occupiers, and of the natives today'. These areas were probably inhabited by societies to whom iron working had become the basis of life.

While in Rhodesia there is little evidence yet of communities relying entirely on others for their iron, these must have existed, especially in those areas of the country poor in suitable ores. On the other hand, the existence of small localized industries producing solely for their host communities is certain. These are exemplified by those smelters who operated as local demand arose, and who were often directly assisted in their work by their customers. These operatives, whose existence is known in the Matopos[12, 13], Selukwe[42] and Buhera[42], might have required payment in the form of ore, charcoal, or food for the whole operation, or of help with the bellows.

The role of known ore sources in Rhodesian Iron Age economy further complicates the problem of how iron production was organized. It is known, for instance, that men used to go to Wedza from as far afield as Chibi, Selukwe[42], and Mtoko to obtain ore, which they carried home in baskets. Again, Brown has spoken of a site near Que Que where the evidence suggests that people from many different cultural groups came to mine and smelt the local hematite[74]. The Manyubi of the Matopos were another group that sought their ore from far and wide. These examples, in which the avoidance of more local sources is occasionally suggested, indicate possible controlling factors on the use of ore sources such as local political conditions and the occasional breakdown in, or the generally tenuous nature of, trade in iron articles in the nineteenth century, thus necessitating smelting by communities in iron-poor areas.

Trade in ironware is an aspect that has been well covered in Zambia[57, 68, 75–77]. In Rhodesia, where there is admittedly much less material evidence, there is a need to combine typological studies with investigations of impurity and trace-element patterns so that the groupings and origins of ironware from ruin sites, especially Zimbabwe, can be discovered. Again, in such work, it should be borne in mind that the iron trade may flourish on two levels at the same time and in any one area. Fagan has shown that, in Zambia, a wide regional trade existed in ceremonial and other objects requiring greater forging skill, alongside the more localized production and distribution of purely domestic ranges[75]. Such 'exotic' ironware found at Zimbabwe may be of Rhodesian origin. Further, in the late stages of the Iron Age it is important to take into account possible imports of European-made iron articles.

The concept of 'metal-working groups' is often used by those working in the historical sciences[59, 66, 78–81]. This labelling of clans or tribes said to have been famous for their metal-working skills is unfortunate, as it contains the suggestion that such peoples were engaged in mining, metallurgy, and the metal trade, solely, full-time, and during the whole period that they existed as distinct groups. At once it seems that this term may embrace groups in any of the economic states discussed above. In Rhodesia such appellations have been applied to the Karanga[39, 82], the Njanja[7, 10], the Mbire[41, 83], and the Mbara[84], and in some sense might also be justifiably applied to Chibi's people. In some cases, especially the late nineteenth century Njanja, this is certainly fully justified. The Njanja indeed are a case in point; little is known of the political and economic factors governing their operations, or their extent in time. In 1972[19], one very old member of VaRanga's family remembered occasions when he and others would form an armed band, go to Wedza Mountain, mine ore, and then beat off attacks by Chief Svosve's men, until they had smelted enough of the ore on the spot to take home and keep them in hoes until the next expedition. Njanja informants in 1944 hinted at payment made to Chief Svosve for the mining of his ore[7]. Clearly, as a metal-working group, they encountered opposition from people, who would deny them access to the raw materials. Even today the current Svosve encumbent is reluctant to allow outsiders near the workings on Wedza Mountain.

One reason for a group to remain distinct as 'metal workers' is the way in which they retained a monopoly over local raw materials and skills. Iron-working is often said to be a jealously-guarded skill[17, 21, 25]. In Rhodesia, the occurrence of furnaces and smelting debris on hilltops and other less-accessible places has often been taken as proof of this. There are many possible reasons for such selective positioning of operations, of which secrecy might be one, but, in societies where trade is generally not a major factor, there is little need to seek to gain or to retain a monopoly. In fact, the evidence shows that iron smelting in Rhodesia was an activity accepted as a necessary part of economic life bound by occasional taboos but by few social restrictions[12, 13, 42]. Skills were often handed down from father to son, but anyone could learn and practise, provided he had the necessary application and equipment. Certainly, there is overwhelming ethnographic evidence that smelting frequently took place in full view of all, in or very close to villages[11], smelting debris being commonly found in domestic levels in the Early Iron Age of both Zambia[59, 77] and Rhodesia[4]. Loss of motivation and skills must often have resulted when a group was separated from its ore sources, no doubt a common occurrence in the mobile and constantly changing conditions of the African Iron Age.

FUTURE WORK

It may be useful to end by an enumeration of avenues along which continued research might profitably be led.

Ethnography

Ethnographic research must necessarily be based on interviews with tribesmen, and with personifications of the tribal *mhondoro*, especially in

those areas close to known and important ore sources. Such work may cover all aspects of iron production in these societies, and ideally should embrace a complete investigation of the group, following the example of Van der Merwe's work at Phalaborwa in the northern Transvaal[66].

Geology

Since, as explained above, the type of ore used is a major factor in smelting, a complete geological survey of all known ore sources used by Iron Age smelters should be undertaken. As many samples as possible should be taken for full analysis from all quarries, surface cuts, and stopes. In this way the metallurgical properties most sought in these ores will be assessed, and a full appreciation will be gained of the variation in impurities and trace elements throughout each orebody.

Archaeology

The areas most likely to yield a bulk of interpretative material are clearly those adjacent to ore sources. All small finds such as smelting ores, charcoals, and crude blooms should be recovered. As representative a sample as possible of the slags on a site, which will often occur in bulk, should be retained. Ferruginous soil material can be sieved for hammer scale to determine the presence of forging activities where other evidence for these fails. Where furnaces are found, a careful procedure of micro-excavation ought to be carried out to investigate features of metallurgical interest such as depth of charcoal bed, numbers and arrangements of tuyères, and provision for tapping. A further possibility is an assessment of the origin of metallurgical influences and the movements of peoples from the typology of furnaces, as suggested by Sassoon[55], Chaplin[52], and Phillipson[53]. This is deceptively simple, and caution is advisable. Whereas the difference between forced-draught, induced-draught, and simple bowl furnaces are obvious and easy to identify, such things as metallurgical refinements, variation in furnace designs, side furniture, and external decoration may be less easy to follow. Thus, although Ziwa A and Ziwa B are clearly distinct, successive illustrations and descriptions of Njanja furnaces show that the designs of these, while conforming to the same general principle, evolved rapidly and were subject to the personal whims of those who made them rather than to any rigid standards[7–10, 19, 21, 23, 27].

Laboratory Analysis

The ways in which ores, slags, blooms, and finished tools can be investigated by chemical and physical methods have been discussed above. It is possible that the determination of minority and trace elements in slags, blooms, and tools can lead to the location of the ore sources and smelting centres. A major drawback here is one that has received detailed treatment, at least in the archaeology of the European Bronze Age[64, 72]. Until the total variation in chemical make-up is known for particular orebodies, and until the incidence of selective uptake of elements in bloom and slags has been investigated, there can be little joy in attempting to relate impurity patterns and trace-element configurations in slags or ironware to mother ores on these grounds.

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