IRON FABRICATION DURING THE “AGE” OF TIN AND BRONZE IN THE SOUTHERN WATERBERG OF LIMPOPO PROVINCE, SOUTH AFRICA

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Abstract

Ever since the 1908 re-discovery of the pre-colonial tin mines at Rooiberg in the Southern Waterberg of Limpopo Province of South Africa, archaeologists have focused much on tin and bronze production in and immediately around the mines. The interest in this metallurgy means that iron and copper have been overlooked despite the fact that the Southern Waterberg is also home to iron and copper ores that were exploited even before the second millennium CE inception of tin and bronze production in this area. This article explores iron production and consumption patterns at the second millennium CE sites of Rhenosterkloof 1 and Tembi 1 in the Sand River Valley of the Southern Waterberg. The present study specifically examines iron smithing technology through the analyses of blooms and metallic objects. To glean relevant information from the blooms and metallic objects, metallographic approaches of Optical Microscopy (OM) and Scanning Electron Microscopy (SEM) were used. The key findings of this study suggest that the objects are products of indigenous bloomery iron technology, which was widely used in southern Africa during the pre-colonial period. Careful hot and cold working was done to achieve optimal qualities of these pre-dominantly non-utilitarian iron objects. It is also clear that iron consumption patterns in the Southern Waterberg were embedded in the local and regional trade networks that serviced southern Africa in pre-colonial times.

Key words: Iron smithing, blooms, Southern Waterberg, Rooiberg, metallography

Introduction

When people discovered how to turn rocks into metals (smelting) and fabricate the metal into usable objects (smithing and forging), human history was significantly transformed (Miller & Killick, 2004). In Africa, south of the Egyptian pyramids, the precise dating for the inception of this technology is still contested but was undoubtedly associated with iron and copper around the 1st Millennium BCE (Holl, 2009). Like the rest of Sub-Saharan Africa, southern Africa does not have a ‘Copper or Bronze Age’ and the reference to ‘Tin and Bronze Age’ in the title of the article is merely meant to capture and highlight the significance of this metallurgy in this area that hosts one of the sub-continent’s unequivocal cases of pre-colonial tin mining. Although southern Africa was the last region to work metals in Africa, the range of metals worked in Sub-Saharan African in pre-industrial times was the same and involved iron, gold, tin, and copper and its alloys. These metals and alloys had distinct chronologies and roles but all of them were pivotal in the growth, expansion and spread of Iron Age communities as well as the development of complex societies in the region (Maggs, 1992; Childs & Killick, 1993;

Chirikure, 2015). Nonetheless, when compared to other aspects of the African past (such as ceramics), this facet of archaeological inquiry remains under-researched. This study explores the techniques of fashioning and, to a lesser extent, the distribution of iron in the Southern Waterberg of the Limpopo Province (Figure 1).

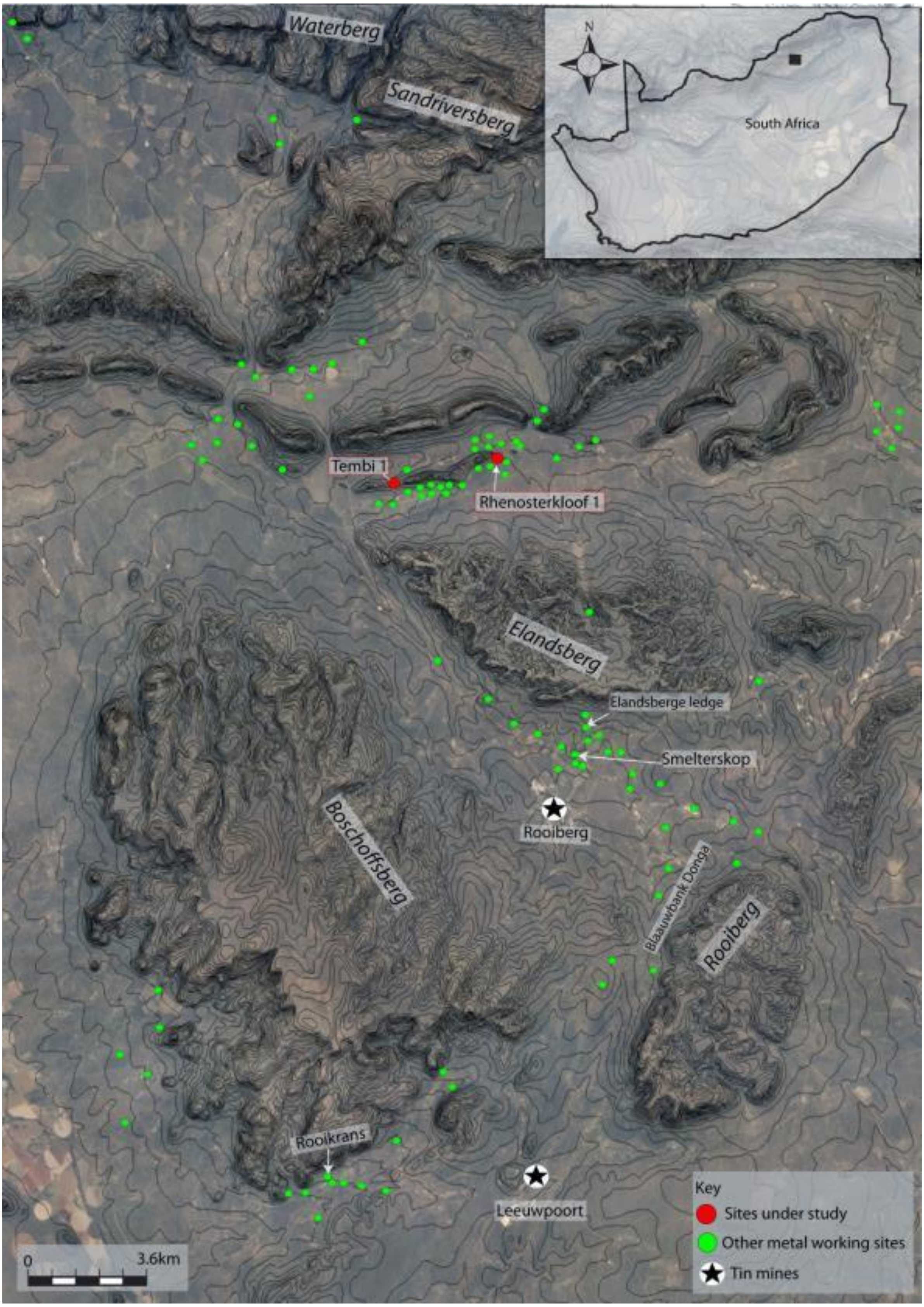
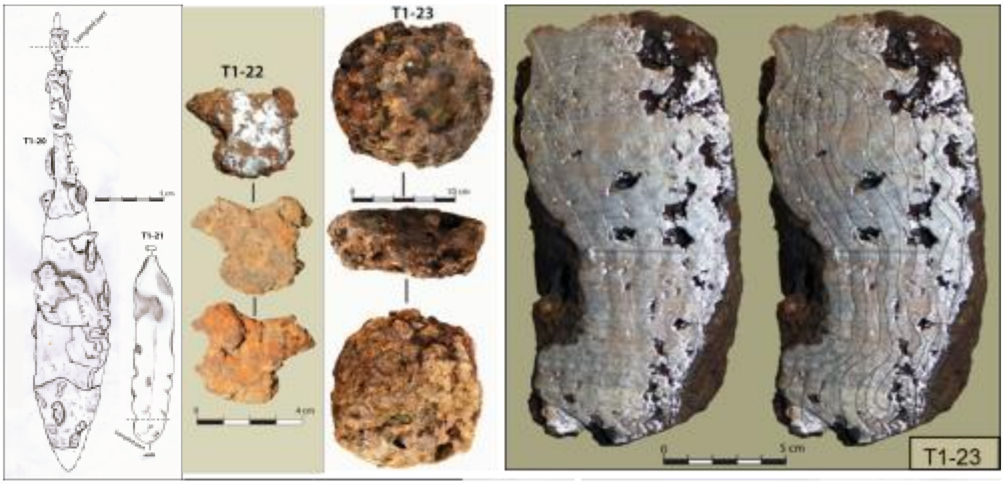


Figure 1: Location of Rhenosterkloof 1 and Tembi 1 in relationship to other key sites in the Southern Waterberg

In the Southern Waterberg, the Second Millennium CE introduction of tin and bronze production against a background of on-going iron and copper working was not expected to do away with iron production, partly because this new metallurgy was neither desirable nor superior in the utilitarian sphere where iron had already eked a permanent place for itself. Tin and bronze production have a special position in this area because of the Rooiberg tin mines that are a unique and unequivocal case of large-scale pre-colonial tin mining south of the Nigerian Jos Plateau (Baumann, 1919; Hall, 1981; Sutton, 1983, Bandama *et al*., 2015). In the Southern Waterberg, more than elsewhere, it would have seemed redundant to continue producing expressive (decorative) iron implements after the introduction of tin and bronze but as demonstrated in the present study, the new metallurgy did not replace on-going ferrous metallurgy. This article does not seek to find out why tin and bronze did not replace expressive iron, but it explores the iron smithing technology that parallels this new metallurgy through the analyses of predominantly decorative ferrous objects from the two Late Iron Age sites of Rhenosterkloof 1 and Tembi 1 in the Southern Waterberg (Figure 2).

Materials and Methods

The iron blooms and metallic objects under investigation come from excavations conducted at Rhenosterkloof 1 and Tembi 1, about 13km from the pre-colonial tin mines at Rooiberg. Culture-historical sequencing and radiocarbon dating place Rhenosterkloof 1 and Tembi 1 in the Rooiberg Phase (1650-1750 CE) (Bandama *et al*., 2013). Located in Rhenosterkloof farm, Rhenosterkloof 1 was first excavated by Hall (1981) before Friede and Steel (1985) exposed two bowl-shaped furnaces. Rhenosterkloof 1's fourteen iron objects under study came from Middens 1 and 2 and Hut Collapse 1 of our 2009 excavations (Bandama, 2013). The other site, Tembi 1, lies immediately west of Rhenosterkloof farm on Koppieskraal ridge. Our 2011 excavations at this extensively stone walled site produced four iron specimens (two blooms from surface context on Metal Working Area 1 and two arrowheads from an excavation context at West Midden 1 and 2) (Figure 2).



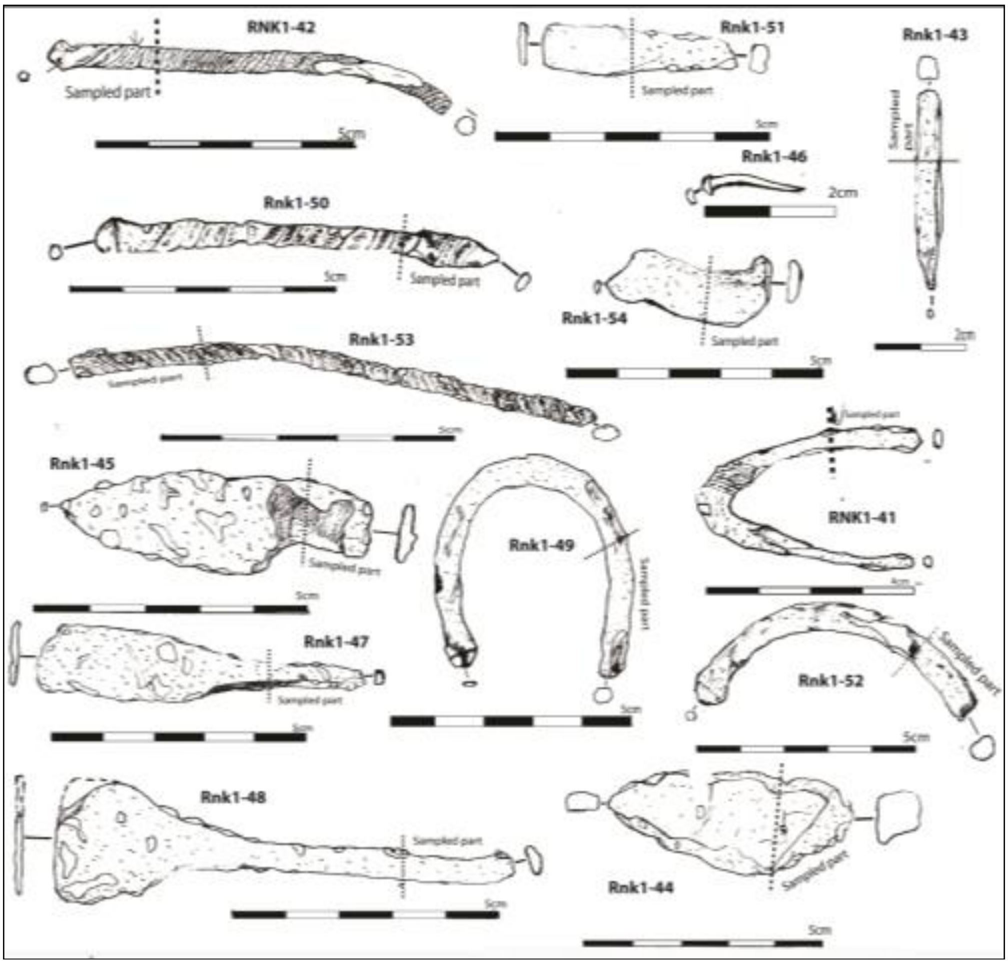


Figure 2: Ferrous objects from Rhenosterkloof 1 and Tembi 1

In keeping with the paucity of large metallic objects at metal working sites in southern Africa, the eighteen specimens represent 100% of all iron objects recovered from the two sites (van der Merwe & Killick, 1979; Maggs, 1982; Holl, 2000; Miller *et al.*, 2001). Large scale iron smelting took place at these sites (about 12 tons of slag for Rhenosterkloof 1 and 1 ton of slag for Tembi 1). The forged objects are generally small (averaging 50g in weight and 9cm in length) but the large bloom weighs 5kg.

All the samples were cleaned, documented and analysed macroscopically before sectioning them for micro-structural analyses. Standard sample preparation procedures for ferrous objects were followed before the analyses of the specimens using Optical Microscopy (OM) and Scanning Electron Microscopy (SEM-EDS) (Bachmann, 1982; Scott, 1991). Sectioned samples were mounted in a resin and hardener mixture to prepare them for grinding and polishing. Metal disks were also cut from the blooms. These disks and the mounted samples were ground manually on water cooled silicon carbide laps from the coarsest grit (800) to the finest (1,200). They were then polished using diamond paste ranging from 6 microns to a ¼ micron, while using an oil-based lubricant. To bring out the micro-structure (grain boundaries and sizes), polished surfaces were etched using a nital etchant (5 % nitric acid and 95% ethanol).

Polished blocks were analysed in a reflected plane-polarised light mode using an Olympus BX51 Microscope. Subsequently, the materials were studied using aFEI Nova NanoSEM Scanning Electron Microscope fitted with an Energy Dispersive X-Ray system (SEM-EDS).

No carbon coating was done on the samples for SEM-EDS analysis. Micro-structural analyses were carried out in the backscatter imaging mode under the following conditions: (i) a working distance of 9.00-20.0mm, (ii) an excitation voltage of 20.0 kv, (iii) a beam current of 1.0 picoAmps, and (iv) a tilt angle of 0.0 degrees and a take-off angle of 35.0 degrees. The acquisition dead time was 60 seconds and the results were expressed as weight percent and normalised to 100%. Area analyses were done on different phases (at least three times) and averaged for the final reading in order to make valid estimates about the bulk composition of specimens.

Analytical Findings

Following standard metallographic analyses (Brick *et al*., 1965; Samuels, 1980; Scott, 1991), it was clear that all the specimens (blooms and forged objects) had not been made from modern industrial metal but derived from indigenous bloomery metal because they had slag stringers (Cleere, 1981; Rostoker & Bronson, 1990; Killick, 1990). The blooms (T1-22 and T1-23) exhibit corrosion products on the outside and were evidently consolidated under a hot forge by flattening projections and tacking together separate fragments of metal (Rostoker & Bronson, 1990) that created deformation lines that are macroscopically identifiable in a cross-section (Figure 2). The polished sections of these blooms show that they are true blooms because more than 50% of the area is metallic iron (Killick, 1990:234). Nonetheless, further hot working would have been required to drive out excess slag from the blooms before they could be forged into usable objects. However, this hammering only reduced but did not remove all the slag stringers as seen in the pre-forms (Rnk1-44) of some iron objects as well as in the finished implements themselves (Figure 3).

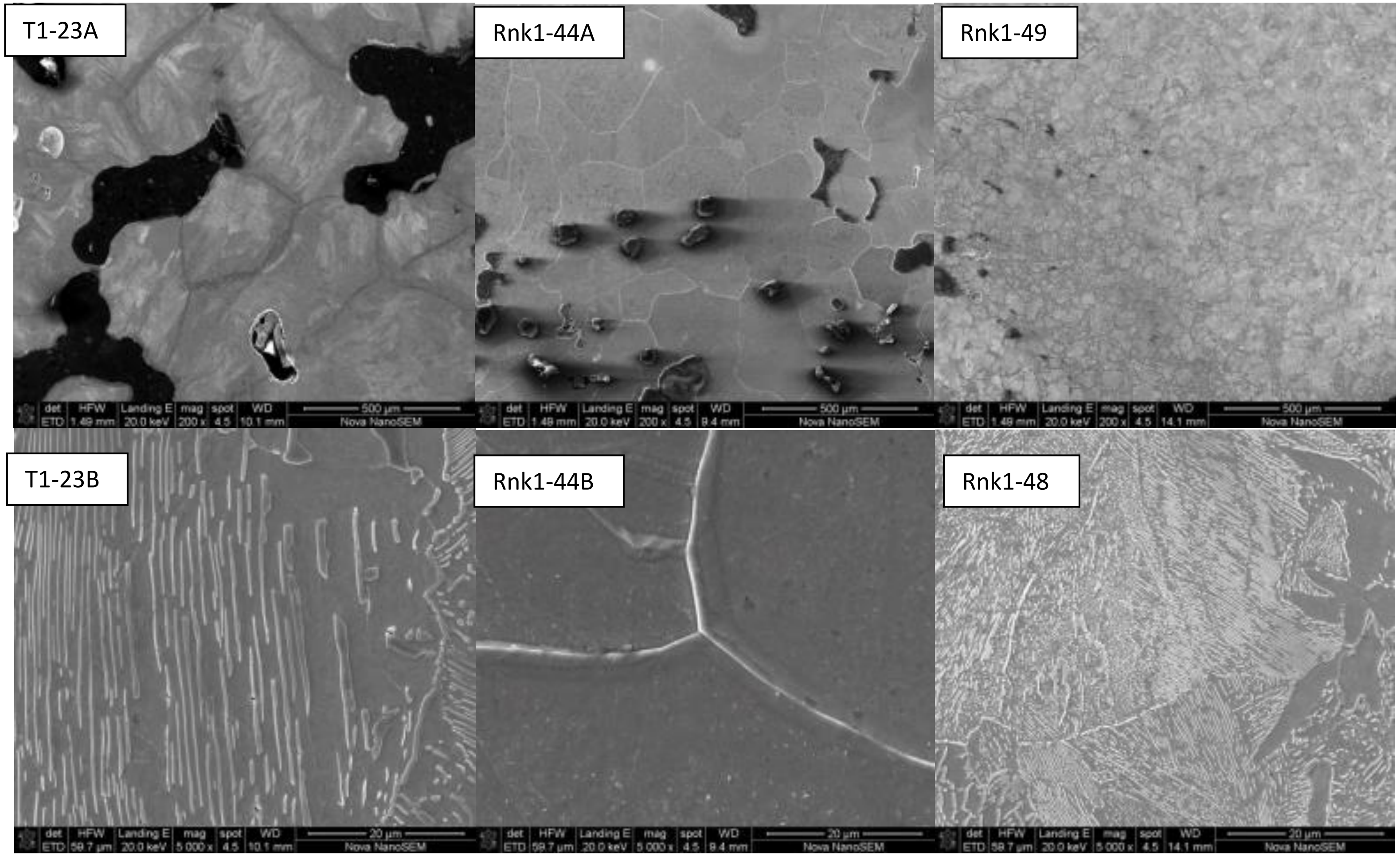
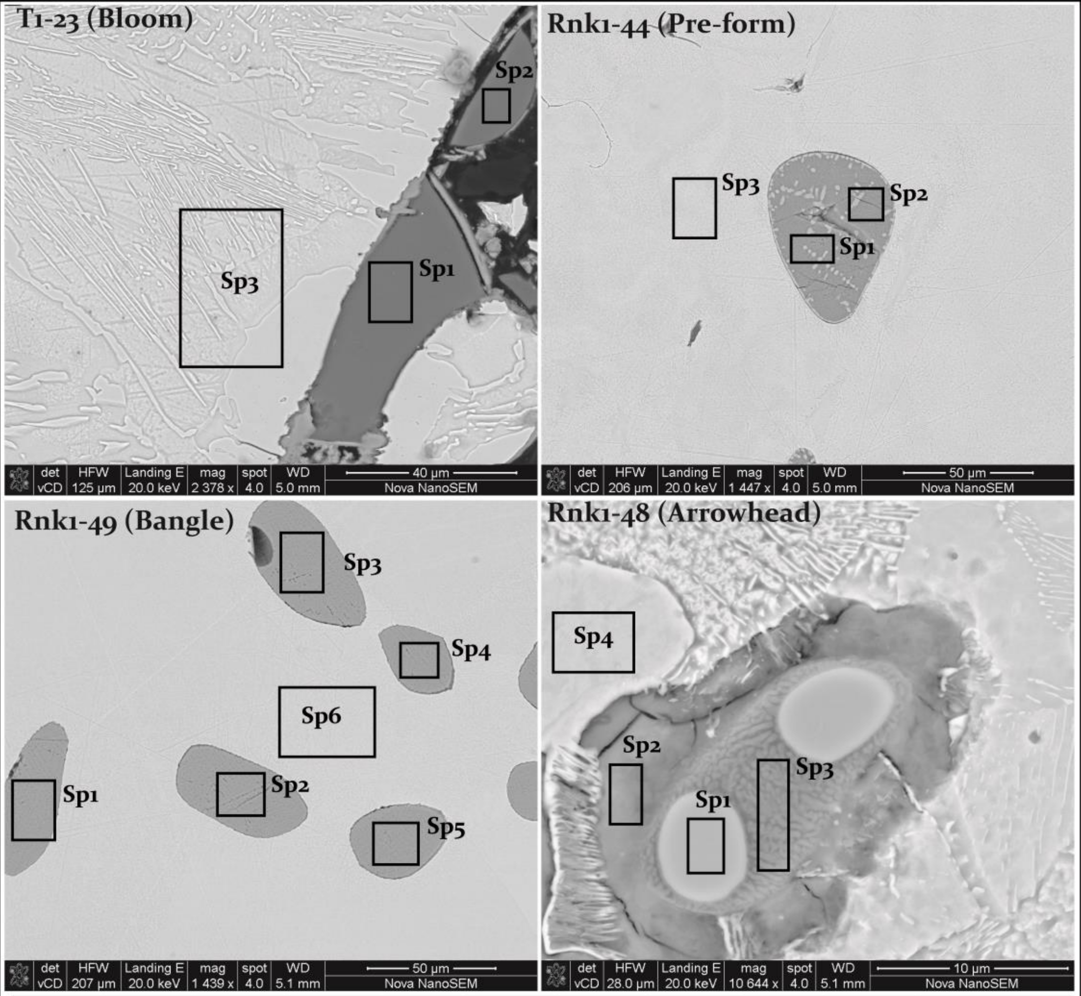


Figure 3: SEM secondary electron images of a bloom (T1-23Aand B), a pre-form (Rnk1-44A and B), a bangle (Rnk1-49) and arrowhead (Rnk1-48). T1-23A, Rnk1-44A & Rnk1-49 were taken at low magnification and show the grain size evolution with hot working. T1-23B, Rnk1-44B & Rnk1-48 were taken at higher magnification to show the effect of hot working on the pearlite lamellar structure

Microstructural analyses of all the objects revealed the appearance of refined microcrystalline grains which decrease in grain size from the blooms (T1-23 and T1-22) ≈ 500μm →pre-form (Rnk1-44) ≈250μm →finished metallic objects≈100μm after forging. The density and size of slag stringers and voids also decrease significantly, with the blooms having the highest. The decrease in grain size is a result of the forging process and it shows that Rnk1-49 had the highest degree of forging as it has the smallest average grain size than that of Rnk1-44 (pre-form) and T1-23 (bloom).

SEM-EDS image analyses of T1-23B, Rnk1-44Band Rnk1-48 show the evolution of the pearlitic matrix with forging. When comparing the microstructure for these specimens, it is clear that both the pearlite interlamellar spacing and the lamellar width decrease from the bloom (T1-23B) to the pre-form (Rnk1-44B) to the arrowhead (Rnk1-48). Pearlite interlamellar spacing is an important microstructure parameter of the mechanical properties; a reduction of the spacing improves the mechanical properties of the alloy. Rnk1-44B in Figure 3 shows extensive fragmentation of pearlite within the ferrite matrix and along grain boundaries indicative of pearlite not being given enough time to precipitate out of solution. The pre-form (Rnk1-44) thus must have been heated to a higher temperature compared to the other 2 blooms which resulted in dissolution of the pearlite, leading to the loss of the normal lamellar structure. In Rnk1-48 (arrowhead) there is reappearance of colonies of lamellae pearlite which implies that the thermomechanical forging was done at a lower temperature (which promoted the precipitation of lamellar pearlite) compared to that of the pre-form (Rnk1-44B).

Using SEM-EDS the composition of the samples was determined and the results showed the heterogeneous nature of both the blooms and the metallic objects.



Sample	Spectrum	MgO	Al2O3	SiO2	K2O	CaO	MnO	FeO	Total	Area analysed
T1-23	Sp1	1.43	9.14	64.81	10.16	9.54	1.98	2.95	100	Slag inclusion
T1-23	Sp2	1.65	9.14	62.76	8.30	12.82	1.33	4.01	100	Slag inclusion
Rnk1-44	Sp1	0.81	3.56	22.91	2.21	3.00	2.16	65.35	100	Slag inclusion
Rnk1-44	Sp2	0.00	4.14	21.81	2.26	2.61	2.41	66.77	100	Slag inclusion
Rnk1-48	Sp1	0.79	3.12	16.16	1.26	2.20	1.89	74.58	100	Slag inclusion
Rnk1-48	Sp2	0.00	4.03	17.46	1.09	2.22	1.62	73.59	100	Slag inclusion
Rnk1-48	Sp3	0.00	3.41	17.25	1.14	2.09	1.30	74.81	100	Slag inclusion
Rnk1-48	Sp4	1.11	2.75	17.49	1.21	2.07	1.68	73.69	100	Slag inclusion
Rnk1-48	Sp5	0.00	3.29	16.57	1.80	2.21	1.41	74.71	100	Slag inclusion
Rnk1-49	Sp3	0.00	3.57	24.63	1.56	6.66	1.99	61.59	100	Slag inclusion
Rnk1-49	Sp2	0.00	0.00	6.59	0.00	1.76	0.00	91.65	100	Corrosion
Sample	**Spectrum**	**Mg**	**Al**	**Si**	**K**	**Ca**	**Mn**	**Fe**	**Total**	**Area analysed**
T1-23	Sp3	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100	Metal
Rnk1-44	Sp3	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100	Metal
Rnk1-48	Sp6	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100	Metal
Rnk1-49	Sp1	0.00	0.00	1.07	0.00	0.00	0.00	98.93	100	Metal
Rnk1-49	Sp4	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100	Metal

Figure 4: SEM-EDS micrograph and compositional data of the bloom from Tembi 1

NB: The micrograph shows ferro-siliceous inclusions and voids in consolidated masses of iron metal.

The SEM-EDS results show that the blooms are relatively free of ‘problem’ impurities such as sulphur and phosphorous. These impurities are notorious for causing hot or cold shortness in iron but they were rarely a problem in most pre-industrial blooms (Rostoker & Bronson 1990). Only silicon was detected in significant quantities in the occluded slags, with the rest of the minor elements being residual in the blooms. This element (silicon) does not affect the physical properties of the blooms in any way when it is less than 1% but the readings for T1-23 suggest that further hot working of the bloom may have been required before it could be forged into a finished product. For T1-23, the retention of significant amounts of occluded slags in the bloom was mainly beneficial in protecting the specimen from oxidation but it also inhibited cold working because the slag inclusions make it brittle (Rostoker & Bronson, 1990). While further hot working was necessary to remove excess slag stringers in the sample, the fact that the bloom was shaped into a flattened ball may suggest that the specimen was at this point ready for distribution. Similar shaped blooms are known to have been broken down and shared among furnace labourers (Tessman, 1913) or between the furnace operators and the owner of the ore (Sassoon, 1964), carried from smelting centres to smithing areas (de Barros, 1988) or simply traded in this form (Rostoker & Bronson, 1990).

Just like the blooms, the rest of the iron objects from Rhenosterkloof 1 and Tembi 1 were corroded but most of them still retained sound metal below the oxidised surface. These objects are plain carbon steels (with ferrite, cementite and pearlite), whose microstructure is varied in keeping with their composition and mechanical and thermal history (Greaves & Wrighton, 1957; Brick *et al.*, 1965; Samuels, 1980; Scott, 1991; Miller, 1992a). Ferrite is a soft and ductile low carbon phase of iron capable of containing up to 0.02% carbon in solution (Miller, 1992a). On slow cooling, it typically forms large polyhedral grains but relatively rapid cooling, such as cooling after normalisation, results in crystallisation into the characteristic laths that give rise to the Widmanstätten structure and appears white under a microscope, when etched (van der Merwe, 1980). Cementite, on the other hand, is hard and brittle iron carbide (Fe_3C) which forms in small quantities at grain boundaries in very low carbon steels (Denbow & Miller, 2007). In higher carbon steels, cementite crystallises in a typically lamellar intergrowth with ferrite to form a eutectoid called pearlite, of which carbon is about 0.8 % (Denbow & Miller, 2007).

Both hot and cold working of iron objects appear to have been practiced with the specimens under study. Hot working between 700˚C and 1,000˚C allows the metal to be shaped plastically and results in elongated slag inclusions that were identifiable in the iron artefacts under study (Miller, 1996). The hot worked objects appear to have been normalised and air cooled relatively slowly as shown by the presence of the typical Widmanstätten structure. With small objects such as the current suite, welding was unsurprisingly not evident (Childs, 1991). On the other hand, cold working (at temperatures lower than the critical range or near ambient temperature) may leave traces of grain deformation and fractured glassy inclusions or strain lines that are also susceptible to corrosion attack (Miller, 1996). Forging the objects in oxidizing environments decarburised the high carbon smelting products (blooms) and there were no signs of intentional hardening processes such as quenching or carburisation. The isolated occurrence of high carbon areas in the samples is a sign of uneven and ‘unintentional’ carburisation of the blooms during smelting (Stanley, 1931; Schultz, 1950; Friede, 1979; Friede & Steel, 1986; Rostoker & Bronson, 1990; Miller, 2001; 2002).

Discussion

Metallographic studies of iron objects from the Southern Waterberg have been limited and focused on chisels recovered from the pre-colonial tin mines in Rooiberg (Frobenius, 1931; Stanley, 1931; Schulz, 1950; Miller, 1992b). The consensus is that these iron gads are soft iron-carbides and not Wootz steel as originally suggested by Frobenius (1931). However, it is doubtful whether these iron objects would have been able to attract this research attention if they were not associated with the tin mines. Indeed, the current study is the only example of a study that has sought to explore iron smithing metallurgy in its own right and not as an appendage to tin or bronze production research (Grant, 1994). The blooms and metallic specimens targeted for this study come from sites that are slightly outside the immediate core area of the pre-colonial tin mines.

The recovery of blooms (T1-23 and T1-22) on the surface at Tembi 1 raised questions about their chemical and physical make up. For instance, were these specimens really blooms or just pieces of meteoric iron? If they were blooms, was there anything chemically or physically ‘wrong’ with them that could have led them to be discarded on the surface at the site? Another critical question relates to whether these objects were products of the indigenous bloomery process or modern blast furnace process. To address these issues, metal samples were cut from the specimens and polished for optical and chemical analyses using OM and SEM-EDS.

The blooms were mostly hot worked in smaller and shallower furnaces because of the very limited furnace wall fragments recovered at contexts related to this activity at Tembi 1. Hot working of blooms ensured consolidation and tacking together of small pieces of blooms, as well as driving out occluded slag (Rostoker & Bronson, 1990). On the other hand, the forging of iron objects was fairly simple and limited to hot and cold working, with occasional annealing but without quenching or tempering (Miller, 2001; Killick, 2009). Brown’s (1995) ethnographic observations of the production of twisted bangles (bracelets) in Kenya, is consistent with our interpretations. Brown (1995: 64) notes that bracelets such as these require about two to three re-heatings to complete the twisting, before the resultant waves on the bangle are hammered out, upon cooling. If required, hardened edges for utilitarian objects would have been obtained by cold working alone, even though this partially weakened the objects and made them susceptible to corrosion (Rostoker & Bronson, 1990). Grain deformation and fractured slag inclusions in this specimen are testimonies that cold working was practiced (Miller, 1996).

It is interesting to note that iron objects were also used in the expressive sphere despite the fact that tin and bronze were also worked at these sites. Clearly, the demand for the decorative iron in this area lies outside of its mechanical hardness which is higher than tin and bronze or copper. Instead, the impetus for decorative iron may consequently be sought in its symbolic value which could not be satisfied by the new metallurgy (tin and bronze) or even copper. For instance, in Kenya, twisted iron bracelets and neck rings which are insignia of smiths and their families, are also used by non-smiths as protective devices against evil spirits (Brown, 1995:64). Just like in the present case, decorative iron also paralleled copper metallurgy, with the two metals sometimes twisted together to form one bracelet (Brown, 1995). Closer to the study area, amongst the Shona people of Zimbabwe, ethnographic work also confirmed that iron (particularly hoes) were sometimes more preferable over other prestige goods such as gold, ivory, cloth and beads because it was a convenient store of value (Childs, 1991; Childs & Dewey, 1996; Wingfield, 2000). Thus, hoes had a universal exchange value; these were needed by the majority of the population for agriculture and were easily converted into weapons and ritual items for the ancestral spirits. This may well be the explanation why iron production continued to parallel, and in some cases outpace, tin and bronze production in the Southern Waterberg (Bandama *et al*., 2015). This is unsurprising because "technologies, objects and forms draw on a reservoir of cultural beliefs that prescribe their use and give them their communicative power" (Herbert, 1996: 645).

Iron artefacts were generally scarce when contrasted with the large amounts of slag produced at Rhenosterkloof 1. Corrosion may explain this paucity but the presence of better preserved smaller implements at the same site suggests that the majority of the blooms and other finished objects were recycled and traded out or even used as funerary goods, as was the case elsewhere (Crew, 1996; Holl, 2000). The context of metal production at Rhenosterkloof 1 clearly suggested that the scale of production was completely out of proportion to the extremely small homestead it was associated with (Bandama *et al*., 2013, 2015). Recently, Bandama *et al*. (2018) suggested that the paucity of quantities of exotica may suggest the local nature of trade in this area, whereby intermediaries exchanged locally viable commodities such as grain and animals. This may partially explain why iron continued to eke its place beyond the utilitarian sphere in this area because its production fed into the local and regional trade network. The large-scale iron production at places such as Rhenosterkloof 1 and 2, and tin production at Smelterskop are reminders of how metallurgists in this area responded to pulses of local and regional demand by producing intensively (Bandama *et al*., 2015). Indeed, in an area best known for its metallurgical riches, it makes business sense to continue producing for all spheres (utilitarian, decorative, economic, spiritual, etc). African metallurgy continues to remind us how the symbolic sphere often trumps the functional focus.

Concluding Remarks

The present study is based on a suite of blooms and predominantly decorative small iron objects from two sites in the Southern Waterberg. Large blooms weighing up to 5kg were recovered at Tembi 1 while a suite of solid bangles and a few other small iron objects were reported at Rhenosterkloof 1. At both sites, these iron objects were recovered in contexts dated between the 16th and 17th centuries, a time when tin and bronze production were in full swing in this area that also hosts unique and large-scale pre-colonial tin mines. This raises sustained interest in decorative iron objects as demonstrated at Rhenosterkloof 1, both intriguing and informative of the prowess and appeal of one of the longest serving metals of the subcontinent. Technical and technological findings place the objects within the broad range of known bloomery smithing of southern Africa, with the signature recovery of slag stringers excluding the option of recycling industrial metal. Hot and cold hammering, coupled with wire twisting, were practiced to produce these seemingly simple objects. Yet the symbolic load of such objects is a permanent reminder that the African appreciation of metallurgy, like other crafts, cannot be adequately explained in pure functional lenses.

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