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Archaeometallurgical Explorations of Bloomery Iron Smelting at Mutoti 2, an Early Iron Age Site in Venda, Northern South Africa

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Abstract: When established, bloomery iron smelting profoundly transformed farming communities that settled in Africa south of the Sahara. Sustained research in the Lowveld region of northern South Africa identified multifarious evidence of metal working dating to the Early Iron Age (Common Era 200-900). Not surprisingly, the region is celebrated in oral traditions, myths, legends, and other reservoirs of local knowledge for its highly skilled metallurgists who reduced exceptionally rich magnetite (Fe_3O_4) and hematite (Fe_2O_3) ores at locales such as Tshimbupfe, Tshirululuni, Vuu, Thomo, and Thengwe. However, the technology of iron smelting and how the smelted iron (Fe) transformed producer and user communities in the region is a subject that, until recently, attracted limited archaeometallurgical work. We present the results of archaeometallurgical analyses of iron production remains from Mutoti 2 using complementary macroscopic (physical examination), microstructural (Optical Microscopy), and compositional techniques (WD-XRF). The results show that the technology of iron smelting fitted within the bloomery method. However, the quantities of iron production remains at the site suggest a scale and organization of production geared for needs beyond single villages. This embedded first-millennium CE iron production into the socio-economic, political, and environmental transformations that shaped the political economy of farming communities of the time.

Keywords: archaeometallurgy; bloomery iron smelting; crafts; economy; early iron age; venda; South Africa

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1. Introduction

It is generally believed that accompanied by crop agriculture, animal husbandry, pottery making, and settled life, iron production was introduced to southern Africa through the demic diffusion of ancestral Bantu populations early in the first millennium of the Common Era, hereafter CE [1–3]. When on the landscape, ancestral Bantu populations developed through time, adapting to different socio-cultural environments. Although there are remarkable continuities between first- and second-millennium CE farming communities, there are also some differences that prompted archaeologists to divide the history of these populations into two groups: Early Iron Age (EIA) (CE200-900) and Late Iron Age (EIA) (CE1000-1800) [2]. However, for the Limpopo Valley, a Middle Iron Age (CE1000-1300) has been added [4]. Generally, it is assumed that iron technologies sustained the shifting cultivation regimes practiced by the Bantu communities in the first and second millennium CE. Forest clearance, preparing the land for planting, and weeding and harvesting millets and sorghum are some of the areas where iron tools would have played vital roles in food production. However, the significance of iron extended beyond utility: it was wrapped in changing ideas of transformation and symbolism that fully embedded technology in society [5,6]. Iron tools were often used in ceremonial settings including royal investiture [7]. As with technologies such as agriculture, pottery making, and house construction, iron metallurgy was a materialized cosmology. For these and other reasons, studies of ancient iron production are a fruitful avenue of exploring not just the skills and knowledge of the iron workers but also the epistemologies, ways of doing, and ways of knowing of the populations associated with traits that are now known with the shorthand-Bantu [8].

Guided by this pervasive significance of iron technology, we dedicate our attention to the little-explored technology of Early Iron Age iron production in northern South Africa. In this region, archaeological evidence of indigenous metal production has been recorded across the Lowveld region in places dating to the Early and Late Iron Ages such as Silver Leaves (EIA) [9], Eiland Salt Works (EIA) [10], Nanḓoni [11], Phalaborwa (LIA) [12–16], Mapungubwe, (EIA) [17], Musina, [18–25], Kruger National Park (EIA) [26–30], and among others Vuu-Tshimbupfe (LIA) [31], with more than 20 metal production sites recently geo-referenced near Nsami River around Thomo Village [32]. Metal-production sites are well represented by dense or scattered slag concentrations, broken burnt *dhaka* fragments from collapsed furnaces, ore, hammer and anvil stones, and broken pieces of tuyere fragments. Some of these sites revealed the existence of agropastoralist settlements with iron production debris dating as early as CE 350 to the late 19th and early 20th centuries when industrial technologies slowly took over. The later sites (CE1200-1800) are associated with the vhaVenḓa, Shangaan, and Bapedi polities [33,34].

During the Early Iron Age (EIA), metallurgy is generally thought to have been limited to the exploitation of iron and copper ore for the manufacturing of utilitarian and decorative objects [4,6,35]. In northern South Africa, very few of these sites such as Thomo have been subjected to standard archaeometallurgical research [31] as compared to the Middle and Later Iron Age sites in the Limpopo Basin (e.g., Mapungubwe), Phalaborwa (e.g., Shankare), and the Kruger National Park (e.g., Thulamela) [13,21,30,36]. Ultimately, the absence of regional datasets on first-millennium CE metallurgy invites explorations of the full production chain, paying attention to the technology associated with EIA metal production. We study the iron production remains from the Early Iron Age site of Mutoti 2 (Figure 1) using standard archaeometallurgical techniques to understand the different stages in the metal-production cycle, and make conclusions about the nature and efficiency of the technology. The significance of this study is that it highlights continuity and change in technological practice, and at the same time allows us to make inferences about the role of metallurgy in the political economy and other aspects of everyday life of past societies [5,6,15,37,38].

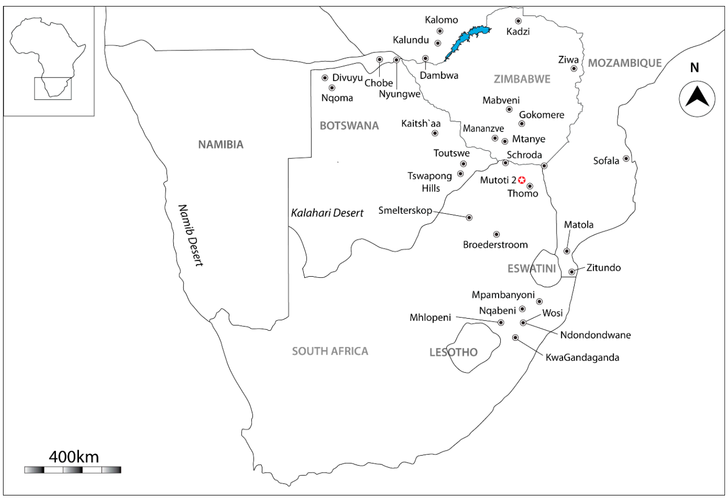

Figure 1. Location of Mutoti 2 in relation to other Early Iron Age sites recorded in Southern Africa.

2. Background to Mutoti 2

The now submerged EIA site of Mutoti 2 (22°58′53.75″ S 30°35′50.47″ E) was originally situated on the summit of a small hill formed on the banks of the Luvhuvhu River south of the Soutpansberg, and 15 km southeast of Thohoyandou in the village of ha-Mutoti (Figure 1). As part of the pre-development heritage impact assessment and mitigation in advance of the construction of Nanḓoni (meaning the place of the furnace) Dam in 2002, the site was excavated before being inundated with water. Edwin Hanisch initially excavated the site in 1997 as part of a Cultural Resource Management Programme commissioned by the Department of Water Affairs and Forestry (DWAF) to salvage the archaeological materials of the archaeological site for curation and future research at the University of Venda [39]. Then, in 1998, Archaeo-Info Northern Province took over the work [40].

Geologically, the area in and around Mutoti 2 is dominated by the Soutpansberg groups (volcanic rocks) and the Drakensberg basalt of the Lebombo Mountains [41–43]. Generally, rich sections with varied minerals have been recorded throughout the area of Venda where Mutoti 2 is situated, for instance, iron ore (magnetite [Fe_3O_4] and hematite [Fe_2O_3]) sources were recorded at Vuu, Tshivhulana, and Thomo [31]. Some old iron ore mines characterised by open pits and trenches were recorded near Vuu village. These were exploited by the renowned iron smelters at Tshimpufe [12,28,32,44]. Judging by the quantities of production remains from iron smelting at Mutoti 2, iron ores played a significant role in the economy of the EIA communities. The diverse vegetation of the area dominated by the Lowveld Bushveld (Figure 2) also offered multiple opportunities—for example, by providing wood for construction—for meeting energy requirements in domestic and craft-related activities.

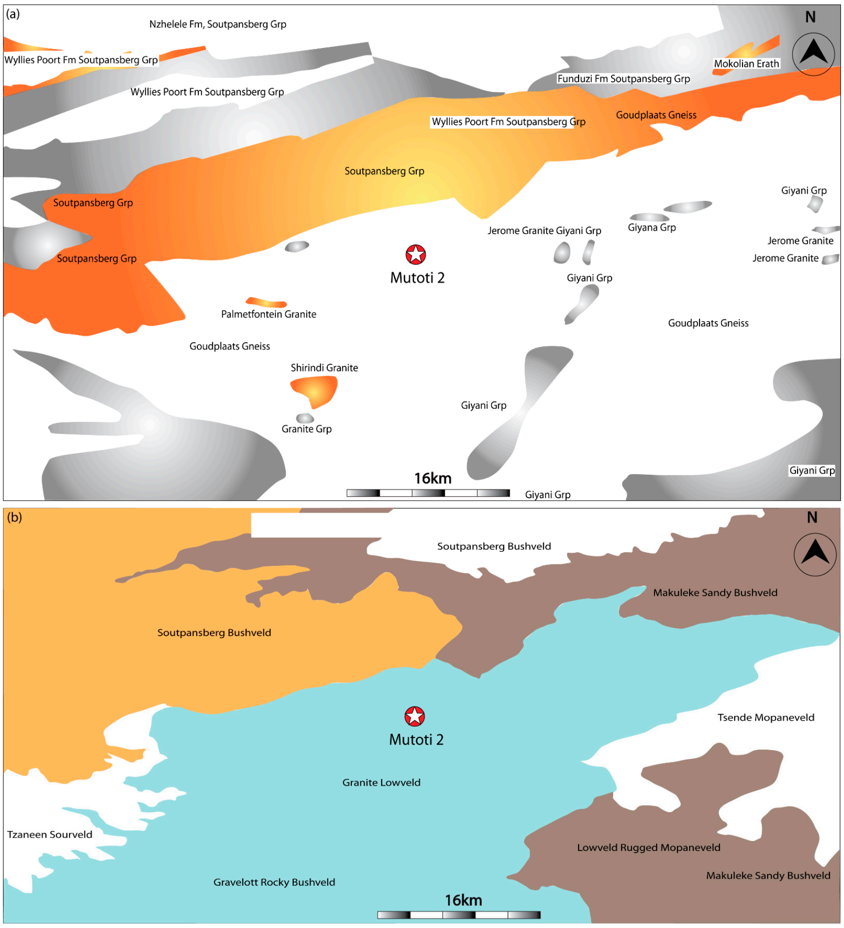

Figure 2. The geology (**a**) and vegetation (**b**) around the Early Iron Age of Mutoti 2.

The rescue work carried out at Mutoti 2 identified significant iron production remains comprised of tuyeres, collapsed furnace remains, and ubiquitous amounts of slag in contexts associated with remnant settlement structures, features, and midden debris covering 18,000 sq metres of residential space. Other remains included 40 grain bins, underground storage pits, animal bone, EIA potsherds, two fragments of brown- and blue-glazed pre-Islamic wares from the Middle East, and 23 house foundations with gravel floors and *dhaka* walls with pole impressions. The local pottery includes features of the Urewe and Kalundu EIA traditions [4]. Available radiocarbon data suggests that Mutoti 2 was occupied between CE 640 and 983. We sampled remains of slag, ores, and technical ceramics for detailed laboratory investigations.

3. Materials and Methods

Samples of iron production remains comprised of ores, smelting slag, bloom fragments, smithing slag, and tuyeres were systematically sampled from the Mutoti 2 collections stored at the University of Venda. The samples were studied in the Materials Laboratory, Department of Archaeology, and in the Geological Science Laboratories of the University of Cape Town. The selected samples were cleaned first, weighed, photographed, and sectioned into three pieces: (1) reference collection and (2) mounting for Optical Microscopy (OM) using an Olympus BX51 Dual Petrographic/Metallographic microscope with an attached digital Olympus Camera, and supported by Olypmus Stream Software) (all manufactured by Olympus UK, Milton Keynes). (3) A portion was ground into a powder for Wavelength Dispersive X-Ray Fluorescence (WD-XRF) analysis to acquire relevant quantitative datasets. Twenty-five samples were mounted in epoxy resin and polished to a $\frac{1}{4}$ micron diamond finish following standard archaeometallographic protocols in the Materials Laboratory.

For reasons to do with costs, 10 samples were submitted for Wavelength Dispersive X-ray Fluorescence (WD-XRF) to quantify essential major and minor oxides compositions in the Geological Sciences Department of the University of Cape Town. The samples were crushed and ground into powder, weighed, and left to dry in an oven overnight at 100 °C. Loss on ignition (LOI) was determined by passing the ground sample powder through several blasts with progressively higher temperatures until no changes were detected. Subsequently, the powder was fused using borate-based flux in a Malvern Panalytical Ltd. Claisse Fluxer (Malvern, UK and pressed to form disks for WD-XRF analyses using a Panalytical Axios XRF spectrometer (Malvern Panalytical Ltd., Malvern, UK) [45,46].

4. Results and Discussion

We first report the results of macroscopic analyses, followed by Optical microscopy, before ending with compositional analyses. The discussion follows thereafter. Metal production debris such as slags, technical ceramics (furnace walls and tuyeres), and remnant iron ores contain within their physical and chemical structures partial histories of technological processes that they underwent [47–51]. This allows us to reconstruct the technology of iron production associated with the different areas of Mutoti 2. Remains of metal production at Mutoti 2 are distributed in different parts of the site with smelting residues concentrated on outer edges contiguous with the settlement while smithing debris is in close proximity to some of the houses. In smelting areas, broken remains of furnace walls, tuyeres with slagged ends, and ores were recovered together with ores and different types of slag. The ore produced a reddish-brown streak consistent with hematite. The slag appeared in various forms from the blocky type consistent with slag, which solidified in the furnace to fairly elongated ropy kinds with clearly defined flow structures.

Iron-bearing minerals such as hematite can be visually identified based on their distinct reflectances. Samples of iron ore were qualitatively and visually studied using reflected plane polarised light microscopy. The studied samples were dominated by iron oxides with very few phases of clay and other minerals (Figure 3a). This was confirmed through WD-XRF analysis of ores. The analysed ore sample is virtually 'clean' with 99 wt% iron oxide (Table 1). The silica (SiO_2, 0.10 wt%) and alumina (0.43 wt%) levels are all very low. The ore has more magnesia (1.28 wt%) and titanium (1.39 wt%) oxides. Very pure hematite is rare in nature, raising the possibility that the studied ores were magnetite that was roasted in the furnace, transforming it into hematite.

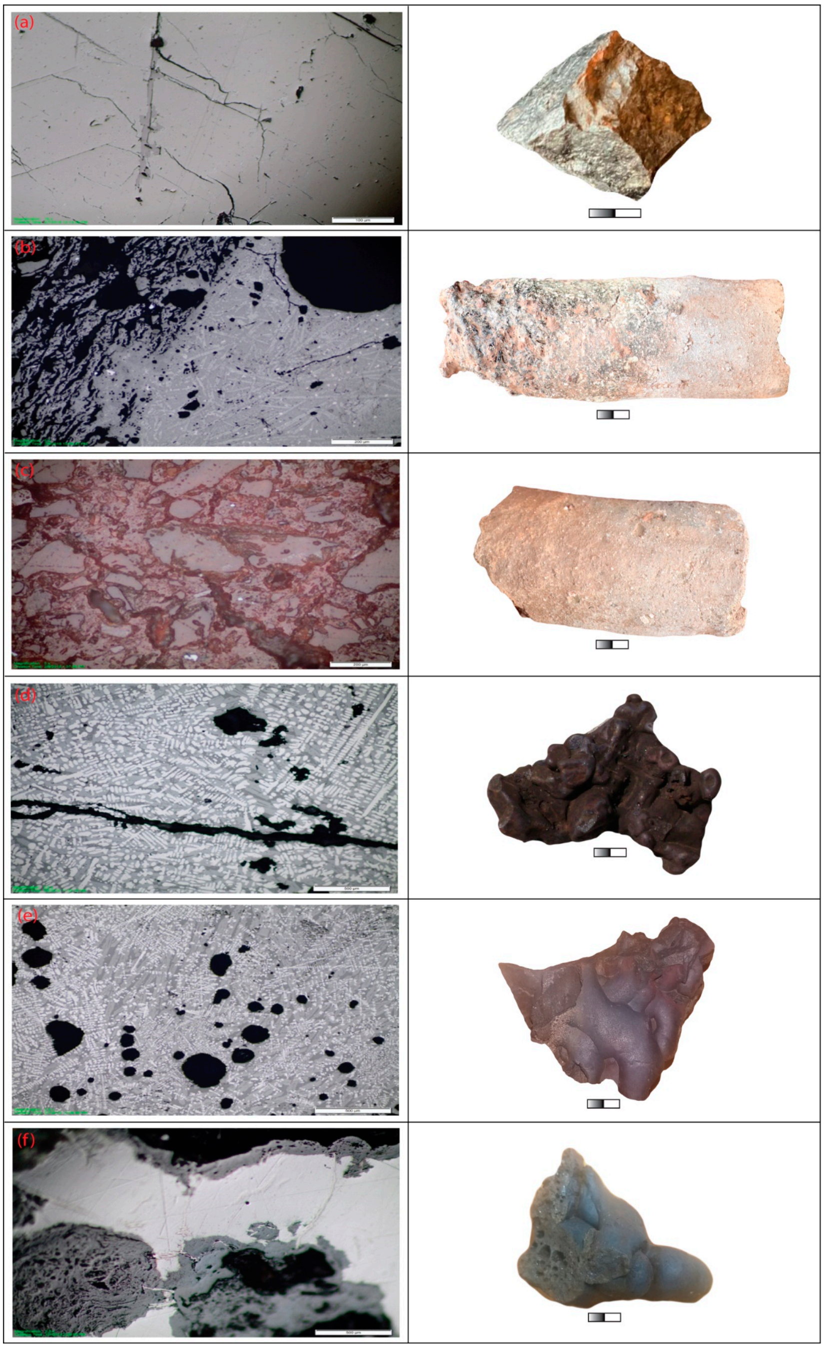

Figure 3. Photographs, and photomicrographs of (**a**) Mut2/98/ore 02 (partially heated ore) specimen showing iron oxide with thermal cracks and little to no gangue minerals; (**b**) Mut2/98/Tuyere/011/02 specimen showing contact between the melting ceramic and the slag. The melting ceramic is porous with occasional bright white metal droplets while the slag is dominated by skeletal crystals of fayalite in a glass matrix; (**c**) Mutoti 2/98/Tuyere/011/ showing quartz crystals and porosity in a clay matrix; (**d**) Mutoti 2/98/Slag/013/02 slag sample showing elongated fayalite, porosity and dendrites of wüstite embedded in a matrix of glass; (**e**) Mutoti 2/98/Slag/009/01 slag specimen showing the abundance of wüstite dendrites, porosity, dark glass, and fayalite crystals; and (**f**) Mut2/98/Slag/001/01 bloom specimen showing metallic iron surrounded by corrosion products.

Table 1. WD-XRF readings for iron production debris recovered from Mutoti 2.

Sample	Mutoti 2 99/Ore 03	Mutoti 2 98/Slag 013/01	Mutoti 2 98/Slag 009/01	Mutoti 2 98/Slag 009/03	Mutoti 2 98/Slag 001/02	Mutoti 2 98/Slag 001/03	Mutoti 2 98/Tuyere 011/01	Mutoti 2 98/Tuyere 011/03	Mutoti 2 98/Tuyere 011/05	Mutoti 2 98/Tuyere 011/07
SiO_2	0.10	17.51	22.20	13.51	17.59	16.89	63.91	61.80	63.52	63.22
TiO_2	1.39	4.85	0.47	0.45	0.32	0.24	1.26	1.01	1.45	1.29
Al_2O_3	0.43	7.07	4.78	3.30	3.37	3.19	18.01	22.97	17.08	19.14
Fe_2O_3	99.26	69.99	73.07	84.72	78.35	77.08	9.22	7.76	10.47	9.47
MnO	0.26	0.42	0.10	0.07	0.03	1.16	0.08	0.08	0.10	0.06
MgO	1.28	2.17	1.01	0.89	0.98	2.40	0.83	0.53	1.03	0.78
CaO	0.00	0.70	1.36	1.10	1.12	1.97	0.96	0.40	1.49	1.15
Na_2O	0.34	0.36	0.51	0.47	0.64	0.53	2.20	0.61	2.22	2.08
K_2O	0.00	0.31	0.78	0.57	0.63	0.57	1.53	1.57	1.90	1.63
P_2O_5	0.02	0.18	0.22	0.18	0.33	0.42	0.04	0.01	0.10	0.03
SO_3	b. d	0.02	0.02	0.01	0.03	0.04	b. d	b. d	b. d	b. d
Cr_2O_3	b. d	0.01	b. d	0.02	b. d	b. d	0.02	0.01	0.01	b. d
NiO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
H_2O^-	0.03	0.18	0.17	0.10	0.37	0.26	0.02	0.84	0.06	0.37
LOI	−2.89	−4.39	−5.01	−5.36	−4.07	−5.10	1.01	2.05	0.09	0.78
Total	100.23	99.41	99.70	100.05	99.70	99.68	99.26	99.67	99.54	100.04

b. d = below detection.

Turning to another category of remains, samples of furnace wall and broken tuyere fragments had relatively large grains of quartz in their fabric, which were visible macroscopically. The quartz was rounded, suggesting that it was in the clay and was therefore not deliberately added as temper. Some fragments of the furnace walls were vitrified in the interior and had thin layers of attached slag. The tuyeres were slagged on the exterior of ends that were placed into the furnace. A heat gradient could be seen in the section, from the interior with the ceramic fabric intact to the exterior attacked by the slag. Under reflected plane polarised light, the slags attached to tuyere ends microstructurally resembled smelting slag and were dominated by olivines and wüstite (Figure 3b). However, sections that were not slagged were dominated by thermally fractured quartz grains, interspersed with porosity and clay minerals. Often, the furnace temperatures were high enough that individual grains of iron oxide in the clay matrix had been reduced to highly reflective droplets of metallic iron. Compositionally, the tuyeres have elevated amounts of silica (between 60 and 63 wt%) and alumina (between 17 and 22 wt%). The amounts of calcium and potassium are variable but generally very low.

The microstructures showed that the slags were typical products of bloomery iron smelting, dominated by elongated crystals of the olivine fayalite, dendritic, and occasional egg-shaped wüstite, all on the glassy matrix (Figure 3d). Some of the slags were very porous with large gas bubbles. The presence of skeletal fayalite and dendrites of wüstite implied that the slag with flow structures cooled rapidly. Compositionally, the slags are very rich in iron ranging between 70 and 80 wt%. There are very limited amounts of the fluxing alkali and earth alkali oxides in the slag. It would appear that about 20% of the iron oxide in the ore was converted to metal while the remainder combined with the melting technical ceramics and the fuel ash to form slags.

Some of the samples previously classified as slags turned out to be highly magnetic and rusty. When sectioned with a saw, it became clear that they were metallic iron, attacked by corrosion in some parts. In one sample, unreduced ore was surrounded by metallic iron, suggesting that the reduction had not fully converted all the ore into metal. Microscopic analyses basically confirmed macroscopic observations. These materials were dominated by metallic iron and were often surrounded by corrosion rings. Slag inclusions in the metal were fayalitic and resembled the microstructures of smelting slags. These materials were interpreted as crown material or bloom fragments that for unknown reasons were not consolidated into metal through primary smithing (Figure 3f) [31,52].

Bringing together, the microscopic and compositional analyses of the Mutoti 2 iron production remains, it becomes clear that iron was smelted in areas contiguous with settlement in this very large first-millennium CE site. The remnants of furnace walls and tuyeres with slagged ends when combined with finds of iron-rich ores point to smelting processes. However, the bloom fragments also suggest that reduced iron was consolidated into usable billets on site, completing the sequence of production operations. Mineralogically and chemically, the tuyeres were dominated by silica interspersed with clay minerals. WD-XRF results showed that the levels of alumina were consistent across the samples. The tuyeres and furnace walls were sufficiently refractory to withstand the temperatures reached in the furnaces. The high amounts of iron oxide however showed that perhaps the technology relied on the melting ceramics to provide part of the fluxing materials during the reduction of very pure ores with nearly 100 wt% iron oxide. The slags are all very rich in iron oxides with minimal amounts of fluxing alkali and earth alkali oxides. It appears that some of the titania in the ore and ceramics were inherited by the slag, establishing a genetic relationship between these different inputs into the system. Given the possibility that high-grade magnetite with few accessory minerals was smelted, it is possible that the smelters may have added sand (as a flux) to facilitate slag formation during the smelting process [49]. However, the very high amounts of iron oxide in the slags suggest that most of the iron oxide was retained in the slag. This may suggest that actually, the technology was self-fluxing with the fuel ash and melting technical ceramics providing the flux. If sand was added, then the benefits in terms of converting more iron oxide to metal were either not fully realised (70–80 wt% iron oxide is a lot) or were not much. When plotted on a three-component ternary diagram, the ore, slags, and ceramics all fall on a line, showing a hereditary relationship between them (Figure 4). Although the phase diagrams make assumptions about equilibrium conditions to describe processes in non-equilibrium, they are useful for estimating phases and temperatures achieved in bloomery furnaces [49]. Most of the slags plot in the left-hand corner, near the wüstite phase, reaching convergence with microscopic observations.

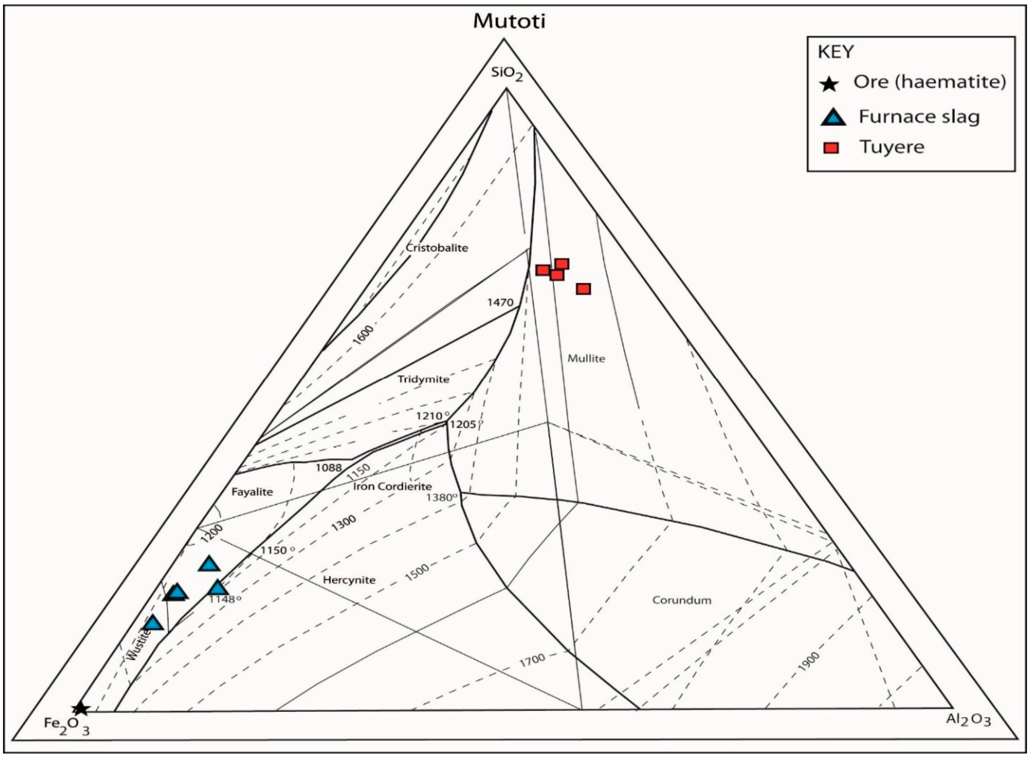

Figure 4. Ternary plot diagram for Mutoti 2 site.

The scale of iron production was fairly large and beyond the needs of individual households. The spatial distribution of ironworking remains at Mutoti 2 suggests a separation of smelting from smithing within the confines of the village. Perhaps, for practical reasons, iron smelting activities were mostly located on the edge of the settlement. It appears as if smithing activities took place in spaces in between houses where numerous hammer and anvil stones were recorded. The archaeological site of Mutoti 2 was strategically located near a major perennial Luvhuvhu River. It can be argued that its population was not excessively huge. This is buttressed by the absence of big middens, within the 18,000 sq metres of the occupational area where 23 houses and 40 grain bins were recorded [40]. However, as the population of the area continued to increase, some people might have moved north and north-east of the site. The river would have been an important source of water for industrial activities as well as for supporting a typical farming way of life. The entire region abounds with resources suitable for iron production. Geologically, typical high-grade iron ores are well known around Mutoti and at Tshimpufe mountain south of the Luvuvhu River (Figure 2). The clays would have been locally available for building furnaces [53].

This general settlement location characterised by a preference for river valleys where resources supporting agro-pastoral lifeways abounded resonates with recorded cases in areas such as Kadzi in northern Zimbabwe [1], Mananzve [54], and among others in KwaZulu-Natal such as Ndondondwane [35]. The iron produced by the smelters would have played an important role in food security and land clearance for agriculture. This is buttressed by the large number of grain bins and underground storage pits that were uncovered in association with homesteads at Mutoti 2 [32,40].

Although the scale of iron production during the first millennium CE was relatively modest compared to later periods, the working of iron at Mutoti 2 was beyond subsistence needs. It appears as if iron production was part of an economy that may have been regionally focused. In the KwaZulu-Natal region, agro-pastoral metallurgists were making iron for exchange with different groups including foragers [35]. The Tswapong region of Botswana is also considered an important hub for a regional economy based on iron production [4]. A survey of EIA iron production by Chirikure [55] showed that iron production became, with time, a springboard to economic and social power. In the case of Mutoti 2, the inhabitants were also networked within the regional economy and the Indian Ocean where they obtained ceramics from distant lands such as the Middle East. Therefore, the production might be considered village-based specialisation which supplied iron to a wider region. Although a bit speculative, the northern parts of South Africa have always been known for specialised village production of iron. This condition was created by the availability of suitable raw materials such as iron ore, easily accessible hardwoods, and water along perennial rivers. The area's relative proximity to the Indian Ocean and other areas in southern Africa conferred its strategic advantages.

In historical times, the Schuynshoogte 29LT farm located south of the Luvuvhu River bank is well known for specialised iron production [31,44,53]. The area making up this farm hosts complexes of iron production sites and mining areas well represented by exposed trenches. Bullock [56] referred to this area as the Iron Mountain. The Tshimbupfe furnaces, perhaps the most well-known component of iron smelting in this region, were known for iron production beyond the village. Interestingly, despite talk of specialisation, no huge mounds of slag have been documented by archaeologists. Based on this comparison, it is possible that the Mutoti 2 production was specialised even though there is no large concentration of production debris. In fact, in southern Africa, specialised systems do not have large dumps of slag [49]. The Mutoti 2 EIA village yielded finds of ceramics from the Middle East. This suggests the presence of connections with the Indian Ocean rim where its community supplied manufactures like iron and other commodities such as ivory and animal skins to Swahili and Arab traders. It is believed that EIA sites such as those further up the Limpopo Valley at places such as Schroda [57] participated in local, regional, and international trade. Mutoti would have been part of the same circuit. That Mutoti played an important role in the regional economy is further supported by a wide range of finds, including local products such as roughly carved soapstone objects which were obviously sourced from distance. Perhaps, part of the iron would have been used as a medium of exchange.

5. Conclusion

This study revealed some important aspects of the technology of metal-making among the Early Iron Age societies of the Lowveld region in northern South Africa. The technology of production conformed to the bloomery process which left a very high percentage of iron in the slag. Judging from the available data, it can be concluded that metal production at Mutoti 2 was aimed for both homestead and communal consumption. This placed iron firmly within the local and regional economies. However, more research is needed to broaden our understanding of Early Iron Age metalworking consumption patterns across the region.

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Data Availability Statement: The datasets generated in this study comprised of samples, photographs and spreadsheets with analytical results are curated at the University of Venda, a public education institution where they are publicly accessible.

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