Investigating the ironworking remains in the Royal City of Meroe, Sudan

Chris Carey, School of Environment and Technology, University of Brighton. C.j.carey@brighton.ac.uk
Frank Stremke, Stremke Archaeology, Bremen
Jane Humphris, UCL Qatar

Introduction
The ironworking remains at the ancient royal city of Meroe, Sudan (Figure 1) are amongst the most famous in Africa, and have attracted archaeological attention since the early twentieth century (Sayce, 1912, 55). Early excavations focused on revealing impressive temples and monumental architectures (e.g. Garstang et al., 1911), rather than the excavation of the slagheaps that were readily visible across the cityscape. Some of the earlier considerations of iron working at Meroe followed a culture history perspective in explaining diffusion of iron technology across North Africa (e.g. Trigger, 1969), although this evidence was largely derived from the occurrence of iron artefacts in graves, rather that excavated evidence of iron production technology. Meroe was considered fundamental to both the supply of iron to ancient Egypt (Sayce, 1912, 55; Török, 1997), and to the origins of iron production in sub-Saharan Africa. Stylistically, Meroitic iron production was likened to the practices of Roman smelters (Tylecote, 1982, 41), and was assumed to have been inspired from the north. However, these models of cultural-historical diffusions of iron production were built on a limited understanding of the archaeometallurgical remains at Meroe.

It was Peter Shinnie (Shinnie and Bradley, 1980; Shinnie and Anderson, 2004) who excavated several large trenches around Meroe starting in 1965, and who first undertook some systematic excavation of some slagheaps (assisted by the archaeometallurgist Ronnie Tylecote), whilst attempting to gain a wider understanding of the archaeological deposit sequences. Importantly, Shinnie’s excavations revealed 6 furnaces and two, (possibly three although this is unclear from his excavation) furnace workshops on the north mound (Shinnie and Kense, 1982; Shinnnie and Anderson, 2004, 77—79; Shinnie, 1985; Tylecote, 1970; 1982). However, other than these finds of furnace workshops, few in-situ furnaces have been found at Meroe (see Humphris and Carey, 2016), which is surprising given that large slagheaps are visible across the surface of the city.

Further to the mapping and excavation undertaken by Shinnie and his team at Meroe between 1965-1984, a subsequent generation of archaeologists continue to investigate its archaeology, including the Royal Enclosure (Wolf et al., 2008; Mohamed-Ali et al., 2012) and the south mound and
Investigating the archaeometallurgical landscape of Meroe

Although multiple papers detail the analysis of archaeometallurgical remains from ironworking, including slags, pyrotechnical infrastructure and iron metal (see for example Humphris and Rehren, eds, 2013, papers therein), there has been relatively little written on how archaeometallurgists investigate landscapes. There are examples of exploration of landscapes to detect archaeometallurgical remains, using relatively intensive fieldwalking techniques (e.g. Pryce et al., 2011), and combining remote sensing topography and field visits with surface collection for laboratory analysis (e.g. Hendrickson et al., 2017). However, how a structured investigation produces a systematic and relevant sample of ironworking evidence within a defined survey area remains a significant issue requiring further critical discussion. The approach undertaken in this study was to undertake surface mapping, integrating this with sub-surface prospection of wider parts of the cityscape, before limited excavation at target locations.
Surface mapping

This current project produced accurate maps of the site, as questions remained about the accuracy and detail of earlier maps (from Shinnie and Kense, 1982; Shinnie and Anderson, 2004). The mapping of slagheaps, and also spoil mounds created by archaeologists who had previously worked at Meroe, was essential for basic site understanding, as well as providing a sounder topographic reference for the archaeological deposits. This remapping used phase differential GPS, total station and aerial photogrammetry. Ground based survey involved mapping the surface extent of visible deposits and features, and creating a GIS database of the composition through surface observation. Through this surface mapping it became apparent that much of the cityscape now visible is a product not only of the original archaeological remains, but also the activities of archaeologists in the twentieth century. These archaeological investigations have created a number of spoil mounds around Meroe, often immediately next to the original excavation (Figure 2). These spoil mounds have been identified as those created by Garstang in the early twentieth century, those created by Shinnie in the mid twentieth century, and other spoil heaps created through excavation, but the origin of which is unknown. These spoil mounds are now an important feature of the cityscape at Meroe, and could easily be confused with in-situ archaeological remains. Furthermore, construction of the railway has created dumped deposits, caused by driving the railway through part of the cityscape, as well as a modern rubbish dump to the north of the city (light pink).

In addition, thirty four slagheaps have been recorded, varying in size from very small (c. 4.5m²) through to the largest slagheap of MIS4 (1692m²) (MIS refers to Meroe Iron Slagheap which has been investigated during this project; non investigated slagheaps are unnumbered) (Table 1, Figure 3). The MIS 1, 2 and 3 slagheaps were originally recorded as discrete features from their surface distribution, although recent excavations (Humphris ongoing research) has suggested these might represent the surface expression of one larger heap (as depicted in figure 3). The location of these surface slagheaps is marked, with a strong predominance to the east of the Royal Enclosure. This was potentially a deliberate positioning of the iron smelting furnaces that avoided possible inundation during the annual Nile flooding, whilst also maintaining agricultural land close to the river, and ensured smoke and soot from smelting did not blow into the Royal Enclosure with the prevailing westerly winds. There is also a distinct bias in the size distribution of the slag deposits, based on their surface measurements. When these slagheaps are categorised by their visible surface area, the small heaps of less than 200m² (red) cluster mostly to the north east of the Royal Enclosure; the medium size (green) slagheaps of between 200 – 1000m² are scattered from the
north mound to the south mound of the site; while the large slagheaps (blue) of 1000m$^2$ or greater are to be found to the east of the Royal Enclosure. This simple analysis demonstrates a difference in the surface spatial distribution of the categories slagheaps based on size (i.e. scale of production remains), and requires explanation, in terms of chronology, technological organisation or site taphonomy.

**Sub-surface investigations**

Prospection methods were used to investigate the subterranean deposit sequences of a number of the MIS slagheaps. The sub-surface surveys used gradiometer data to map the physical extent of the magnetic contrast of the slag deposits and identify possible furnace locations, with such techniques well established for the investigation of ironworking sites (e.g. Vernon et al., 1998, Carey and Juleff, 2013). Electrical resistivity survey was also used to investigate the sub-surface sediment architecture of the deposit sequence, with other surveys at Meroe demonstrating the potential of this technique (e.g. Humphris and Carey, 2016; Mohamed-Ali et al., 2012), although the arid conditions and sand dominated sediments create challenging conditions for the collection of resistivity data.

The electrical resistivity surveys used a Syscal Pro 72 electrode rig, collecting data on a 1m electrode interval, using the Wenner Schlumberger array. The results from the resistivity transects demonstrate that significant variation exists in the composition of the slagheaps (which has been supported by subsequent excavations). In particular MIS4, the tallest visible slagheap, is composed of slag based deposits throughout much of its volume (Figure 4; for location of the transect Figure 3), with slag dominated deposits labelled as A1, A2, A3 and B, denoted by the higher resistivity values. However, although these are substantial deposits of slag, there is a generally lower area of resistivity towards the base of the slagheap (unit B), and whilst this unit may contain some slag material, its sediment architecture is different. It is likely to include non-slag dominated contexts, and possibly architecture remains (e.g mudbrick buildings). A further area of lower resistivity is also visible (unit D) and this is a possible structure or a deposit with a lower slag content. This can be compared to electrical resistivity survey of MIS6 (not shown; see Humphris and Carey, 2016), which has relatively thin deposits of slag overlying an earlier building. This difference in size and volume of slag deposits between the MIS4 (large slagheap) when compared to MIS6 (medium size slagheap), infers a difference in the organisation of the deposition of iron working waste.
The gradiometer survey used a Bartington grad 601-2 twin sensor gradiometer, walking 30m grids on 1m traverses, sampling every 0.25cm. The gradiometer data spatially defined a number of the slagheaps and also detailed a series of additional surface features across the site, such as the possible pottery kiln or other pyrotechnical structure (Figure 5). Significantly, no new sub-surface slagheaps were identified, although it should be emphasised that gradiometer survey can only penetrate to depths of c. 1.5m, routinely identifying features in the top 1m BGL. However, the north and south mounds at Meroe are deeply stratified with recorded archaeological stratigraphy reaching depths of up to 6m, as documented by Shinnie during his famous Grid Line 50 excavation. Thus most of the archaeological deposit sequence is out of the range of the shallow gradiometry prospection technique. To account for the lack of sub-surface slag deposits detected by the gradiometry survey it is necessary to revisit the Grid Line 50 excavation.

The Grid Line 50 excavation

From 1965-72, Shinnie undertook the Grid Line 50 excavation at Meroe (Figure 6; the reinterpreted section is shown as the green line on his excavation trench). This trench ran for a distance of 120m from east to west, revealing, among many interesting archaeological finds, substantial sub-surface slag deposits (Shinnie and Bradley 1980). This trench was continued during the 1973-84 excavations (although this extension is not included for discussion here as no significant slag deposits were recorded). The Grid Line 50 trench was excavated using standard methods of the time, and the results and documentation cannot be directly compared to modern stratigraphic site recording. Numbers were given to some layers within the section drawings which are described by Shinnie as ‘episodes’ of activity across the cityscape, which can be considered broadly equivalent to modern stratigraphic phases. As contexts were not recorded, no cuts or fills are evident in the section drawings, and some ‘layers’ blend into others, with many deposits not having unique numbers.

The Grid Line 50 excavation provides an indication of the depth and complexity of the deposit sequence in this area of the city, but significantly it also provides an indication of the nature and distribution of the subterranean slag deposits (Figure 7). The section was digitised and some simplistic stratigraphic analysis was undertaken, through the colouring of different types of slag deposits, according to Shinnie’s descriptions. There is a certain degree of simplification of the section presented in this paper, and only the layers that are relevant to ironworking are discussed, therefore the reader is referred back to the original publication for a more detailed description. Episodes that contain concentrated slag are coloured orange; episodes of slag deposition that also contained ash
and sand are coloured green, and sandy deposits that contain some slag are coloured yellow. From the section it is clear that the slag rich deposits dominate the eastern part of the section, with all episodes of slag dumping stopping between I50 and J50, and the western part of the section containing virtually no slag. It is also clear from the section that the vast majority of slag deposits occur towards the middle and base of depositional sequence in the east, within the earlier stratigraphic deposits.

The earliest phase of slag deposition occurs at the base of the sequence as layer 13, and is above a ‘natural soil’ or early land-surface. This deposit is a long thin spread of slag, extending for approximately 25m, with a maximum depth of c. 0.5m. Above this are layers 12a, 12b and 12c, which are interpreted as domestic occupation by Shinnie. Above layer 12 are further slag deposits recorded as layer 11. Layer 11 is again a long thin spread of slag, similar to layer 13, reaching a maximum depth of c. 0.75m. Layer 11 is overlain by layer 10 and is described as a water-lain clay, representing a hiatus of unknown duration between the two earlier episodes of slag dumping, visible as long thin spreads of metallurgical debris (layers 13 and 11) and a second, later phase of slag dumping. This second phase of slag dumping is characterised by a number of medium size heaps, labelled by Shinnie as layers 8 and 6, in contrast to the longer spreads of layers 11 and 13. These medium slag dumps have been re-labelled in this analysis as layers 8a, 8b and 8c and 6a, to recognise the series of discrete dumps. The nature by which Shinnie’s Grid Line 50 section intersects the slag deposits is unknown (i.e. does this clip the end of the heap or run through its centre, etc). However, the fact that in the later layers (8a-c and 6a), multiple medium heaps of slag are intersected, indicates a difference to the earlier phases of activity represented by the longer thinner layers 11 and 13, possibly relating to the technological organisation of the iron production.

No radiocarbon dates are available for layers 8a-c or 6a, and a description of their composition is limited, although Shinnie describes them as including slag, furnace fragments and tuyeres. Postdating these is layer 7, described as a sandy material with some slag and ash, and layer 5, a further deposit of ash and sand, interpreted by Shinnie as probably wind deposited. However, this layer 5 sand deposit is recorded as containing multiple discrete small dumps of slag, labelled in this reanalysis as layers 5b to 5r. These deposits are generally smaller still than layers 8a, 8b, 8c and 6a, although they do represent some variation in size (with the caveat they are exposed in a section that cuts them at an unknown angle). Slag deposits 5b to 5r are the last phase of slag dumping (except for a small slag deposit in layer 4 (401a)), before a significant shift in the deposit sequence to domestic activity, labelled by Shinnie as layers 1 and 2. Layer 2 is described by Shinnie as
representing intense domestic occupation with Meroitic architecture built of sun dried bricks. Although precise dating for these later domestic deposits and structures (layers 1 and 2) is not available, it can be estimated that they date somewhere between 300BC based on the early radiocarbon date from layer 4 and to somewhere around 200AD, based on the early radiocarbon date for layer 1 (although these dates are early in the use of radiocarbon dating and should be treated with caution).

This sub-surface slag distribution presents an interesting narrative with regards to ancient iron production at the site. Shinnie acknowledges 3 episodes of iron smelting, labelled as layers 13 and 11, layers 8 and 6, and layer 5(b-r) (IBID 19), which sit stratigraphically below the domestic occupation of this part of the site. This location, which was as an area used for iron production (assuming the metallurgical debris was not carried far for dumping), was transformed into an area of domestic occupation, with iron production seemingly ceasing at this location. A further interesting dimension to the section are a series of early structures, labelled as structure numbers 13,001, 13,002 and 13,003. During the early phases of slag deposition above the land surface, these are the only recorded walls, and they appear to be coterminous with the early slag deposits. It is possible that the slag was dumped into an older building (as at MIS6), or that these structures were designed to either retain the slag, or that they were originally associated with iron smelting in another way (i.e. that they were the walls of furnace workshops). Again re-excavation and recording would be required to explore this, but they create a further interesting dimension to the ironworking sequence recorded by Shinnie.

Recent archaeological excavations of the slagheaps
Since 2012 excavations have been conducted on seven slagheaps at Meroe (MIS1, MIS2, MIS3, MIS4, MIS6, MIS7 and MIS8; see figure 3). These ongoing excavations involve the systematic collection of archaeometallurgical and archaeological samples for dating and laboratory analysis (see Humphris and Carey 2016 for description of the quantitative sampling). Information regarding the depositional sequences of the slagheaps, and the architectural features that they bury is integral to understanding the evolution of iron production at Meroe. While this paper cannot provide a detailed description of the excavations on these slagheaps (see Humphris and Scheibner, 2017), a number of key themes are presented in terms of chronology and formation.

The chronological framework produced from the excavations indicates that iron production was initially conducted within furnaces situated around slagheap MIS 4, c. 1000m to the east of the Royal
Enclosure. Radiocarbon dates for MIS4 provide a date range from 750BC through to 130BC, although these dates cluster in the seven and sixth centuries BC (Humphris and Scheibner 2017, 383). The rate of metallurgical deposition appears dramatic, perhaps indicating a particularly high rate of iron production during this early period (c. 700 – 300BC). This supposition is supported by radiocarbon sequences obtained from MIS2 and MIS3, which also indicate significant metallurgical waste produced during Napatan times, from c. the mid fourth to the mid second century BC. Recent excavations at MIS4 show the deposit sequence of the upper 2m towards the top of the slagheap to be made almost entirely of iron production debris (Figure 8), with multiple tipping deposits of slag dominated contexts; some of these contexts had significant volumes of furnace infrastructure and some had a significant proportion of sand, associated with the slag. This demonstration of the near continuous deposition of slag dominated contexts in the upper section of MIS4 supports the interpretation of the resistivity data (Figure 4).

This early period of iron production at Meroe, which seems to have ceased in the eastern area of the site by around the first to second century BC, can be contrasted to the excavation at MIS6, whereby the slagheap was formed over and against an earlier mudbrick building (trenches 2 and 4, Figure 9). This slagheap has a much smaller mass of metallurgical debris compared to MIS1, 2 and 3, and MIS4. The iron production at MIS6 has been dated to the late/post Meroitic period, dated from a furnace workshop found within MIS6, which provided dates from an in-situ hearth and furnace of c. 400 – 430AD for the final workshop phase (Humphris and Scheibner 2017, 391). The entire spread of radiocarbon dates from slagheap MIS6 provide a range of 200AD – 520AD, although these cluster towards the fourth century AD. A similar interpretation is suggested for the unexcavated MIS5, of later (Late-Post Meroitic) iron production, due to its small size and location at the top of the south mound. MIS8, located on the north mound has been recently radio carbon dated as a late/post Meroitic slagheap (unpublished results from recent unpublished radio-carbon dating). A similar situation was encountered at Hamadab, where late/post Meroitic iron production waste overlays earlier Meroitic settlement (Humphris 2014).

Integrating the new excavation data with the surface survey highlights an interesting aspect of the history of iron production at Meroe. MIS1, 2 and 3, and MIS4 are deposited from extensive iron smelting which took place mainly in the Napatan and early Meroitic period. The slag deposits at MIS6, (and probably MIS5 by virtue of its stratigraphic position) and at MIS8, date to the late Meroitic and Post Meroitic period. The question then arises: where are the slagheaps and furnaces associated with the Meroitic period (date c. 300BC – 300AD?). As Humphris and Scheibner (2017,
note, there is a minimum current gap in the date ranges of the ironworking slagheaps investigated of at least 200 years covering this period, and the true extent is likely to be greater.

An emerging model
Three pieces of investigation have been presented: (I) the mapping and categorisation of the distribution of surface slag deposits; (II) a re-interpretation of Shinnie’s Grid Line 50 excavation to understand sub-surface slag deposits at the site, and (III) some evidence from our current archaeometallurgical investigations at a number of the slagheaps. Based on these results there is an emerging understanding of iron production at Meroe, although there is significant research to still be undertaken. The iron furnaces at Meroe were consistently positioned to the east of Royal Enclosure. The surface mapping clearly demonstrates variation in the size of slagheaps visible at ground level at Meroe, and in their distribution across the city. The difference in apparent size, combined with recent dating evidence from current excavations, indicates that the largest scale of slag deposition at Meroe occurred during its earliest periods, although it must be caveated there has been a limited amount of excavation within the city.

This interpretation is corroborated (at least for the north mound) by the significant, early slag deposits visible in Shinnie’s Grid Line 50. In fact, if the slag deposits in the Grid Line 50 are representative of the sub-surface deposit sequence in the north mound and/or the south mound, then the scale of production during this early period was extensive. The recent excavations at MIS4 and MIS1, 2 and 3 with associated radiocarbon dating also support this model of large-scale iron production during this early period. One possible stimulus for such large-scale iron production at this time was to supply the Kushite armies with weapons to support their territorial expansions and defences (it is beyond the scope of this paper to consider scale of production in relation to the broader, evolving social, economic and political circumstances of Kush, and the reader is referred to Pope, (2014) and Török, (2015)). Certainly Meroe was an important economic centre during the Napatan period, not least due to its capacity to produce large and essential quantities of iron. This made the city a valuable area for the Kingdom of Kush during the Napatan period (Pope, 2014, 5-33).

The data presented supports the hypothesis that at around c. 200BC, iron production in the traditional locations, stops. The accumulation of metallurgical debris at slag mounds MIS1, 2 and 3, and MIS4, ceases, while domestic architecture is constructed above the slag deposits documented by Shinnie. This is clearly a deliberate choice, and why this occurs, and where production moves to are important research questions. Certainly the change in location of the archaeometallurgical
remains seem to reflect a development of the urban landscape to the east of the site, overtaking the traditional production locations, which, were possibly forced to move to accommodate the development of the city. This is not only evidenced by the domestic archaeology seen in Shinnie’s excavations, but also at MIS1, 2 and 3, where temples are then constructed on the slagheaps. Thus domestic and religious development of the city seems to take precedent, which is associated with impressive imported goods, testifying to a prosperous city (Török, 2015).

If this model addresses the when and why of the shift in iron production locations, the question of where the iron producers moved to remains. The surface mapping undertaken for this study highlights the presence of small surface slag mounds to the east and northeast of the Royal Enclosure. The Grid Line 50 also records a third episode of iron production formed of smaller slag deposits (5b – r), underneath the later domestic occupation. These smaller slag deposits might indicate that iron production was decentralised compared to earlier times, and that the scattering of smaller mounds represents a new freedom on the parts of the smelters to have their own discrete workshops. It is possible that during the period when Meroe was the capital of Kush, that iron production was continued on the peripheries of the city in small workshops, with the north and south mound becoming home to many of the non-elites, as demonstrated by the later domestic occupation in Shinnie’s Grid Line 50 section. It is also clear that iron production is occurring in the post Meroitic period (c. 300 – 600AD), with the surface slagheaps of MIS6 and MIS8 deposited at this time. Whether there is continuity of iron production in this later phase with the earlier phase remains to be tested.

A question also arises as to why such effort was made to create such large slagheaps (e.g. MIS4) during earlier phases of iron production; such a large mound must have been the product of multiple furnace workshops. Centralised organisation is certainly one mechanism, but even so, why go to the effort to walk up the slagheaps and dump material on top of them, rather than simply scattering the debris around the landscape? These earlier mounds were created over hundreds of years of deliberate build up, and the metallurgical remains in Shinnie’s Grid Line 50 also display this same pattern of continual dumping at a defined location. Excavations at MIS1, 2 and 3 have revealed the presence of multiple slagheaps which are then incorporated into one large mound. It certainly appears that this earlier desire to make large slagheaps disappears later on, possibly indicating a changing organisation, to the iron production process.

Conclusion
This paper has presented some interpretations of newly generated data regarding the iron production remains found at the Royal City of Meroe. The integration of surface mapping, with reanalysis of Shinnie’s Grid Line 50, coupled with more recent excavations, have provided a much fuller understanding of the metallurgical remains at Meroe. In particular it appears that the earliest phase of the site (c. 700BC – 300BC) contains the largest volume of iron production waste, curated into large slagheaps. Following this phase domestic and ritual development of the cityscape takes precedent, coupled with a seemingly more scattered distribution of smaller iron production areas across the north and south mounds. This switch in the nature of deposition of the slag deposits is interpreted as change in the organisation of the iron production, possibly becoming less ‘centralised’ over time.

The data presented is only a first step in constructing a model of iron production at Meroe. In particular, systematic excavation of some of the smaller slagheaps is planned in future seasons. These slagheaps have so far witnessed little archaeological investigation, with the larger and medium sized slagheaps having been the focus of archaeological excavation, due to their greater visibility across the city. Secondly, the lack of evidence for iron production during the period from 300BC through to c. 300AD requires explanation and exploration, although the investigation of some of these smaller slagheaps might fill in some of this gap. Another avenue of future research is to use other electromagnetic techniques that can detect sub-surface concentrations of slag, to provide a fuller analysis of the distribution of slag deposits across Meroe. It is hoped that this future research will provide more of this detail on the chronological and spatial organisation of ironworking at Meroe.

Acknowledgements
We thank the National Corporation for Antiquities and Museums (NCAM) in Sudan for supporting and assisting the UCL Qatar research at Meroe, most notably Dr Abdelrahman Ali (director general) and Mr El Hassan Ahmed (director of fieldwork). The contribution of the NCAM inspectors who worked as part of the team during the surveys and excavations is gratefully acknowledged. We also sincerely acknowledge the support of the University of Khartoum. The research presented here is funded by the Qatar-Sudan Archaeology Project (Grant 037) through the support of UCL Qatar (Qatar Foundation). Most importantly, a thank you to all of the project team for their hard work in the field. Lastly, we thank the reviewers for their comments and suggestions to help improve this manuscript.
Bibliography


Figure 1: The location of the Royal city of Meroe, at international, regional and site levels.

Figure 2: The Royal City of Meroe, showing Shinnie’s original map, combined with the recent surface mapping.

Figure 3: Map of the slagheaps at Meroe, colour coded by their size based of surface expression.

Figure 4: The electrical resistivity section of MIS4 with interpretation of the main components of the slagheap (location of transect in figure 3).

Figure 5: Map of the gradiometer data at Meroe, highlighting the slagheaps and possible pottery kiln or other pyrotechnical feature. The gradiometer data did define some structure within the slagheaps, but no new subterranean slag deposits were discovered.

Figure 6: The location of Shinnie’s Grid Line 50 trench, with the reinterpreted section highlighted in green.
Figure 7: The reinterpretation of Shinnie’s Grid Line 50 excavation, showing three early distinct phases of smelting, before domestic occupation.

Figure 8: Location of the excavations on MIS4 and two sections from trench 2, demonstrating the slag dominated deposit sequence in the upper part of this slagheap.

Figure 9: Photographs of iron slag piled over the top of an earlier building at MIS6, contrasting with the top of MIS4. Top photograph MIS6 trench 2; bottom photograph MIS6 trench 4.

<table>
<thead>
<tr>
<th>Slagheap</th>
<th>Height above ground level (m)</th>
<th>Area m²</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>0.8</td>
<td>30.5</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>1.4</td>
<td>43.3</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.6</td>
<td>23.7</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.4</td>
<td>25.6</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.4</td>
<td>43</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.2</td>
<td>14.2</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.1</td>
<td>4.5</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>&lt;0.1</td>
<td>13.4</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.6</td>
<td>7.9</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.3</td>
<td>9.7</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.6</td>
<td>15.2</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.4</td>
<td>6.6</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.6</td>
<td>88.9</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.3</td>
<td>5.3</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>&lt;0.1</td>
<td>47</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>1.6</td>
<td>33</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.5</td>
<td>41</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.1</td>
<td>30.1</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>1.3</td>
<td>92.4</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.8</td>
<td>95.2</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>0.2</td>
<td>13.9</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>2.2</td>
<td>116.8</td>
<td>Small</td>
</tr>
<tr>
<td>MISS</td>
<td>1.6</td>
<td>57.8</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>1.1</td>
<td>151</td>
<td>Small</td>
</tr>
<tr>
<td>-</td>
<td>3.1</td>
<td>569.1</td>
<td>Medium</td>
</tr>
<tr>
<td>Slagheap</td>
<td>Number</td>
<td>Key Dimensions</td>
<td>Colour</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>---------------</td>
<td>--------</td>
</tr>
<tr>
<td>MIS8</td>
<td>4.2</td>
<td>361.2</td>
<td>Medium</td>
</tr>
<tr>
<td>-</td>
<td>0.8</td>
<td>210.9</td>
<td>Medium</td>
</tr>
<tr>
<td>MIS7</td>
<td>3.4</td>
<td>294.5</td>
<td>Medium</td>
</tr>
<tr>
<td>-</td>
<td>1.4</td>
<td>230.1</td>
<td>Medium</td>
</tr>
<tr>
<td>-</td>
<td>0.8</td>
<td>312.9</td>
<td>Medium</td>
</tr>
<tr>
<td>-</td>
<td>1.9</td>
<td>206.1</td>
<td>Medium</td>
</tr>
<tr>
<td>MIS6</td>
<td>3.2</td>
<td>415.9</td>
<td>Medium</td>
</tr>
<tr>
<td>MIS4</td>
<td>4.6</td>
<td>1692</td>
<td>Large</td>
</tr>
<tr>
<td>MIS1, 2 &amp; 3</td>
<td>3.9</td>
<td>7206.9</td>
<td>Large</td>
</tr>
</tbody>
</table>

*Table 1: Slagheap numbers and key dimensions across Meroe (refer to Figure 2 for colour scheme).*
Figure 1: The location of the Royal city of Meroe, at international, regional and site levels.

209x159mm (300 x 300 DPI)
Figure 2: The Royal City of Meroe, showing Shinnie’s original map, combined with the recent surface mapping.

210x296mm (300 x 300 DPI)
Figure 3: Map of the slagheaps at Meroe, colour coded by their size based on surface expression.

297x420mm (300 x 300 DPI)
Figure 4: The electrical resistivity section of MIS4 with interpretation of the main components of the slagheap (location of transect in figure 3).

206x143mm (300 x 300 DPI)
Figure 5: Map of the gradiometer data at Meroe, highlighting the slagheaps and possible pottery kiln or other pyrotechnical feature. The gradiometer data did define some structure within the slagheaps, but no new subterranean slag deposits were discovered.

197x132mm (300 x 300 DPI)
Figure 6: The location of Shinnie's Grid Line 50 trench, with the reinterpreted section highlighted in green.

296x419mm (300 x 300 DPI)
Figure 7: The reinterpretation of Shinnie’s Grid Line 50 excavation, showing three early distinct phases of smelting, before domestic occupation.

161x88mm (300 x 300 DPI)
Figure 8: Location of the excavations on MIS4 and two sections from trench 2, demonstrating the slag dominated deposit sequence in the upper part of this slagheap.

209x150mm (300 x 300 DPI)
Figure 9: Photographs of iron slag piled over the top of an earlier building at MIS6, contrasting with the top of MIS4. Top photograph MIS6 trench 2; bottom photograph MIS6 trench 4.

209x148mm (300 x 300 DPI)