Journal of Archaeological Science 70 (2016) 132–144

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Research Papers

# New methods for investigating slag heaps: Integrating geoprospection, excavation and quantitative methods at Meroe, Sudan

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ARTICLE INFO

*Article history:*
Received 7 September 2015
Received in revised form
26 February 2016
Accepted 15 April 2016

*Keywords:*
Iron slag
Sudan
Geoprospection
Quantitative sampling
Volumetric modelling
Meroitic civilisation

ABSTRACT

This paper describes a multifaceted approach to the investigation of iron slag heaps, focusing on one of the slag heaps at the Royal City of Meroe in Sudan. This study marries together geoprospection data (gradiometry and electrical resistivity transects), topographic data and quantitative excavation data, to provide an analysis and comparison of the total volume, slag component and slag composition of a slag-heap. Significantly, the results demonstrate the limitations of using a topographic only model, but also demonstrate how volumetric modelling must be integrated within quantitative characterisation of slag-heap composition. In this case, quantitative sampling of the slag deposits revealed the composition of the slag assemblage was dominated by a newly defined category of slag which has major implications for reconstructing iron technologies in the Meroitic civilisation. This research highlights the dangers of applying simplistic models and basic investigative strategies to iron slag heaps and furthers the debate on applying volumetric modelling and excavation sampling to unexcavated areas of the finite and important resource of archaeometallurgical deposit sequences.



## 1. Introduction: iron production in the Kingdom of Kush

The Kingdom of Kush was a powerful African State that flourished from around the eighth century BC to the fourth century AD. At its height this kingdom controlled an area encompassing hundreds of kilometres along the east and west banks of the Nile from south of modern Khartoum to the Egyptian delta and beyond (Welsby, 1998: pp. 7–9). Meroe Royal City was the capital of the Kingdom of Kush from *c.* 300BCE to 350 CE. Along with its pyramids, temples and palaces, Meroe is renowned for vast remains of iron production, with slag heaps being prominent features within the landscape of the city environs (see Humphris and Rehren, 2014 for literature concerning Meroitic iron production). Although Meroitic iron production has been studied superficially in the past (Sayce, 1912: p. 55; Arkell, 1961: p. 147; Tylecote, 1970, 1982; Shinnie and Kense, 1982; Shinnie, 1985; Rehren, 1995), a systematic study using modern field and laboratory methods was only initiated in 2012 by UCL Qatar. This research aims to investigate and contextualise the role of iron production within the social, political, economic and environmental contexts of the Kingdom of Kush.

Throughout the Royal City of Meroe the slag heaps vary in size, from less than 10 m to over 50 m in length, potentially indicating chronological differentiation. Of particular significance at Meroe is that while some slag heaps appear to contain mostly metallurgical debris from the upper surface of the heap to ground level, others are comprised of a relatively thin horizon of metallurgical debris above sand and/or earlier architecture, giving the superficial appearance of a slag-heap. This, coupled with the inherent heterogeneous nature of slag-heap deposits, has necessitated an innovative approach to the survey, excavation and sampling at Meroe in order to produce estimates of quantities of raw materials used and iron produced, both major research questions of the investigations. If the potential iron yield from a smelt can be estimated from the slag analyses, then the quantification of the volume of slag within a heap is a critical question (Historic England, 2015: 1, 9, 11, 14). When addressing such research questions, investigations into ancient iron production often include estimates of slag-heap volumes based on macroscopic observations during excavation. For example, Cleere (1971b: p. 206) produced a 50,000 ton estimate for the slag-heap at Beauport Park, Battle, although he subsequently warned about complexity of issues affecting such calculations (1981: pp. 191–193).

The investigation of ironworking site-scapes requires an

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http://dx.doi.org/10.1016/j.jas.2016.04.022

integrated combination of methods to understand ironworking remains at a variety of scales. This paper describes the use of geoprospection methods and quantitative excavation as part of the investigation of slag heaps. It is argued that combining these two methods adds significant data to the ideally multifaceted investigation of the archaeometallurgical deposits. The case study area is located at the Royal City of Meroe, an area famed as much for its pyramids as its rich ironworking legacy. The iron slag-heap is MIS6 (Meroe Iron Slag 6; Fig. 1).

## 2. Investigating slag heaps

The evolution and complexity of ironworking technologies and the associated production of technological debris have been subjects of academic discourse from the Middle Ages through to modern archaeometallurgical excavations (e.g. Biringuccio, 1942;Agricola, 1950; Straker, 1931; Cleere, 1971a, 1971b; Miller and Killick, 2004; Florsch et al., 2011; Perret and Serneels, 2009; Charlton et al., 2010; Killick and Miller, 2014). The fascination with metal producers of the past continues as progress is made to understand their technological innovations and choices, as well as the impacts their technologies and products had on society. The diversity evident in metallurgical processes across space and time is as captivating as the similarities that are dictated by the physical properties of the materials with which they worked and the physical wastes they left behind.

The dominant artefact from the production of iron in the archaeological record is iron slag, often deposited into discrete dumps or heaps. The term *slag-heap* is used here to define archaeometallurgical material dominated by iron slag, although significant variation exists within their deposit structures, including the composition of archaeometallurgical debris and non-metallurgical material/sediment components (Craddock, 1995: pp. 12–15, 204). Variability in composition can occur within and between slag heaps, and at site, regional and (inter)national levels. Technological factors, societal choices and post depositional processes can all influence slag-heap composition. *Archaeometallurgical material* within this paper is used to define all materials associated metalworking, such as slags, furnace lining, tuyeres, ore fragments, charcoal, etc.

Although slag heaps represent the durable waste debris of the production process, archaeometallurgists strive to locate and identify the remains of iron smelting furnaces as the primary evidence of the technological, historical and social aspects of metalworking technologies (Pleiner, 2000: p. 194). However, across many ancient smelting locations, it is the iron slag which forms the resilient, ubiquitous and valuable archaeological remains where furnaces have long since disappeared. In such cases, analytical approaches must be used to reconstruct an understanding of the past ferrous technologies through the investigation of slag heaps (e.g. Cleere, 1971a; Tylecote et al., 1971: p. 342; Gordon and Killick, 1993: p. 247; Juleff, 1996; Birch et al., 2015; Historic England, 2015: pp.

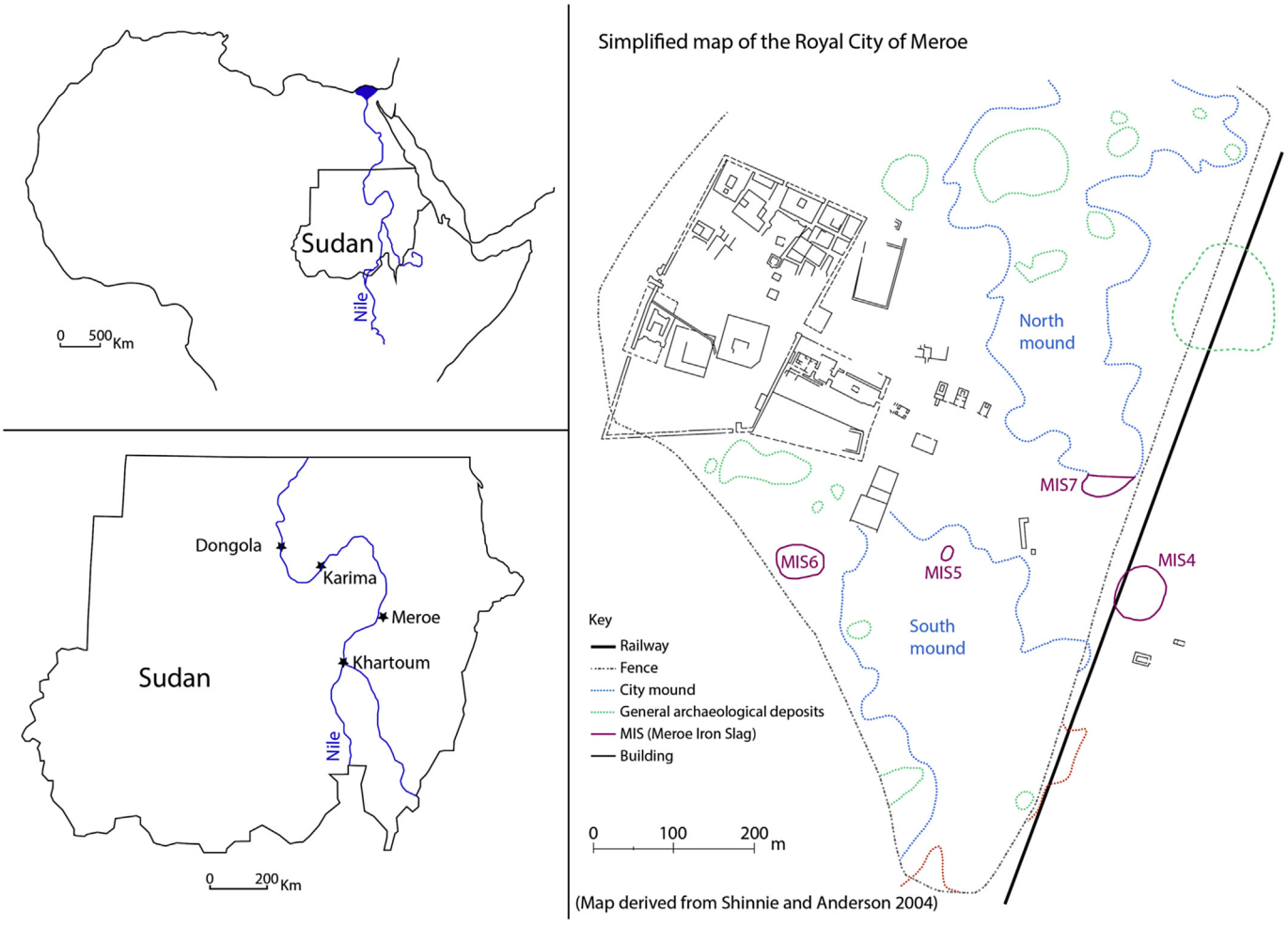


**Fig. 1.** Location of Sudan, with Meroe and a number of other key sites on the Nile marked. Inlay depicting the Royal City of Meroe and the slagheaps mentioned in the study.