Thilo Rehren

Meroe, Iron and Africa

For decades, Meroe and African iron were almost synonymous. Dubbed the 'Birmingham of Africa' in the early days of the 20th century, the tracks of the Cape-to-Cairo railway cutting through the major slag heaps a few hundred yards east of the Kushite capital ensured prominence - and easy access - to this site. It is probably this combination of publicity among a wider circle of historians, archaeologists and travellers within the British empire, and the impressive visibility of the black slag heaps within the yellow sand that contributed significantly to the early reputation of Meroe as the African iron smelting centre. This combined with a Eurocentric, not to say imperialistic, view of cultural superiority of the Old World over indigenous African societies, and their cultural achievements in general, to assign to Meroe a pivotal role in spreading iron technology into an Africa which was apparently without any precursory copper or bronze metallurgy, i.e. obviously incapable of developing a sophisticated technology like iron smelting and smithing on its own. This diffusionist view boiled down to the idea that Ancient Egypt provided its iron-working know-how to Meroe from where it then spread into all of sub-Saharan Africa.

This is not the place to discuss details of the history of research into and perception of African iron technology, a few necessary points with particular bearing on Meroe may suffice. Garstang started excavating Meroe in 1909, tangibly including some of the slag heaps. Sayce, travelling the region soon after, coined the phrase of Africa's Birmingham in 1912, thus contributing to the 'public understanding' of archaeology in his days. Meroe's dominant role as the one and only injection point of iron technology into Africa is first challenged by Cline (1937: 124), who denies Egypt's - and hence Meroe's - contribution to African metallurgy, promoting instead the Berber of the 4th century AD in the western Sudan, today's Tchad (Cline 1937: 141). Arkell (1961) in turn emphasises Meroe again, soon after it was more critically discussed by Trigger (1969) and Amborn (1976). At this point it is necessary to stress that all this discussion and changing interpretation was effectively based on what little archaeological evidence of Meroitic iron metallurgy Garstang had produced before the first World War. It was the excavations by Shinnie and the technical studies of that material by Tylecote that brought about new evidence for the technology and dating of Meroe's iron furnaces (Shinnie & Kense 1982; Tylecote 1982).

While the evidence for Meroe remained virtually unchanged since then, a whole series of sub-Saharan 'iron centres' attracted the attention of archaeologists: particularly in the area of the Great Lakes (Childs 1991a, b; Childs & Killick 1993) and in west Africa (Okafor 1992), dating roughly in the same period as the alleged beginnings of Meroitic iron smelting: The mid first millennium BC. Here appeared autochthonous developments, independent of a northern pollination, and at the best linked by the Bantu expansion (Huffman 1972).

This was the background against which the Volkswagen Stiftung, Hanover, within its scheme for the enhancement of German-German academic co-operation, offered to fund a series of new excavation campaigns in Meroe including an in-depth investigation of the origins, spread and development of Meroitic iron technology within the broader context of the local archaeology. An initial campaign took place in 1992, jointly organised by the University of Khartoum, the Pelizaeus-Museum in Hildesheim and the Humboldt-University in Berlin. This Meroe Joint Excavation (MJE) successfully proved the infrastructural feasibility for the planned major campaigns, and the tremendous potential contribution of a fully integrated science-based archaeological study of the 'industrial quarter' at the outskirts of ancient Meroe to investigate the pertinent questions of African iron technology at the interface of sub-Saharan Africa and the Egyptian cultures. Sadly, and despite all reasonable efforts by the Volkswagen Stiftung, the political problems related to this ambitious project turned out to be insurmountable, to the effect that the main seasons of fieldwork never took place and the laboratory analysis of the samples taken during the initial season had to remain fragmentary. It was therefore decided to publish at least those embryonic archaeometallurgical results obtained so far in a series of papers in the Mitteilungen der Sudanarchäologischen Gesellschaft zu Berlin e.V. (Wenig 1994; Rehren 1995, 1996; Eigner 1996). This paper is a slightly updated English version of the one published by the author in 1995, concentrating on the metallurgical analysis of slags and ores collected in 1992.

THE SLAGS AND ORES

A range of questions was to be addressed during the archaeometallurgical part of the MJE project. Basically, these can be reduced to three major areas of enquiry, namely the amount of metal produced, the technology used to do so, and the chronological aspects modulating these two. The only immediate indicator of the amount of metal smelted was the quantity of smelting slag present at Meroe. To translate this into an amount of metal, one needs to know the initial iron content of the ore and the residual iron content of the slag. The technology used in iron metallurgy determines the yield in iron from a given ore, i.e. the percentage of iron extracted as a metal bloom, and the subsequent loss of metal from this initial material during smithing to transform the bloom into a semi-finished, dense, metal bar or object. The chronological aspects eventually relate to questions concerning the earliest origins of iron smelting in Meroe, and the development in quantity and technology with time.

These three major areas of enquiry in turn required three different approaches. The quantification had to rely on field measurements of the slag heaps, and sampling and analysis of both ore and slag. The technological assessment was to be based on a joint chemical and mineralogical investigation of these samples, while the chronological aspects were to be tackled by excavation and sampling of various layers, and radiocarbon dating. From the outset it was clear that this last point was the most ambitious, and almost certainly unachievable, part of the whole project even if a long series of excavations would have been possible. As it turned out, almost nothing new was gained toward this argument due to the premature termination of the project. This shortcoming reduced the entire research literally to a two-dimensional exercise restricted to quantity and technology, based on material collected from the surface survey, and an initial excavation of part of one major slag mound.

The overwhelming evidence for iron working at Meroe is the tremendous amount of dense, black, slag, accumulated in a number of heaps of different size, that still dominate the landscape immediately to the east of the confines of the city proper, but also extending well into the inhabited part of it. Despite their prominence at the site, it was not before Tylecote (1982) that at least a sketch map of the location of these slag heaps was published, outlining only the major mounds. The obvious need was for a more detailed reconnaissance to determine the volume of slag heaps above surface, and to measure the proportion of slag, furnace wall fragments, and other debris volume per unit of these heaps. In view of the limited time and man power available, and the priority given to establish the main topographic grid to serve the active excavation areas, this survey necessarily had to be done with limited precision. The three axis (width, length and height) of each heap were measured and a volume estimation was done based on the formula for half an ellipsoid body. This led obviously to an over-estimate of the real volume, mainly due to the lower surface inclination of the real body as compared to the ellipsoid model. Since it was also obvious, however, that the slag heaps extended considerably underneath the modern sand surface upon which the measurements were based, it was felt that this geometric overestimate would not overestimate the real, i.e. total above surface and sub-surface volume of each heap. Although neither of these intrinsic errors could be quantified, they were bound to balance out each other rather than to add up. To determine the mass fraction of real slag within a given volume of slag heap material, several samples of 10 litres each were weighed, and then carefully separated in slag proper, furnace wall and related refractory ceramic material, and other debris, mostly domestic pottery, sand and ash. Uncertainties and possible errors in this exercise relate to the fact that only the so-called North-West Mound 1 was included in the excavation in 1992 and thus could be sampled, and that in particular the correct classification of the finer debris often proved problematic. How to distinguish low-fired, now almost totally disintegrated outer furnace wall material from ordinary local soil? It also often proved difficult to tell apart smelting and smithing slags (see below). Based on this survey, and bearing in mind the mentioned uncertainties, the amount of slag proper within the fenced excavation area of Meroe was estimated to between 5,000 and 10,000 tons. The amount of furnace wall debris identified within the slag heaps runs to about the same weight.

The technological interpretation of the slags in the field aimed to distinguish between smelting slags and smithing slags in the somewhat naive assumption that only the amount of smelting slag could then be used to calculate the iron production. However, it soon became obvious that such a clear cut distinction was only possible with some certainty for larger pieces, typically above about half fist size, while many smaller fragments showed too little morphological characteristics to attribute them unambiguously to either of the two processes. Particularly worrying were local concentrations of relatively large quantities of small plano-convex cakes, which from their very shape, and in an European context, would easily be identified as typical smithing hearth bottoms. Here, however, they showed little if any signs of corrosion or rusty areas, and a very restricted internal porosity. In brief, their material appearance was exactly like typical smelting slags, and indeed several transitional pieces indicated the possibility to derive this form from slag solidifying within the bowl-shaped bottom of a smelting furnace. A tentative breakdown between smelting and smithing slags gave the impression of about equal amounts of both.

The analytical work in Bochum then concentrated on those slags which were clearly identified as smelting slags, postponing the investigation of the ambiguous and smithing slags for future work, to be done within the context of the wider project.

The fieldwork included also a survey of the wider region for possible iron ore deposits. The local geology, basically Nubian sandstone, was known to be rich in iron. Indeed, ferricrete sandstone, i.e. sandstone with a significant proportion of iron oxide as a binding agent for the individual sand grains, were used widely as building material in Meroe, and due to its very dark appearance at times was even mistaken for the ore smelted. The survey produced ample evidence for ancient mining in the mountains several kilometres to the east of Meroe, with large underground workings and well preserved tool marks at the walls. These mines, however, worked the sandstone as building material, and no indication whatsoever was found that would put these mines in any relation to the production of iron ore. Iron ore, however, was also found in large quantities, both as rich layers of iron oxide within the sedimentary structure of the sandstone, and as rich crusts of iron oxide developing at the surface. Several samples were taken from both types, and chemically analysed.

The picture as it emerged from the slag survey confirmed the interpretation given by Tylecote (1982). There were large amounts of tap slag, much of it with a flow pattern indicating a tap hole some 20 to 30 cm above the ground, resulting in a peculiar type of slag running down the outer furnace wall before building a larger puddle or pool extending away from the furnace base. This tap slag has a very characteristic surface pattern, with a very smooth, metallic looking upper surface with typical flow structures, and a similarly typical pattern of tiny indentations on the bottom side from where the slag flowed over sand grains. The other prominent smelting slag variety consists of solid blocks of black slag, without any flow structures and apparently solidified within the furnace. Larger fragments typically have a convex outer surface representing the contact zone of the molten slag with the furnace wall. Here, abundant inclusions of white quartz grains, extending up to several centimetres into the slag, resulted in a speckled appearance of these slag lumps. The plano-convex cakes briefly described above, and fragments of them, are the third morphological group which occurred in significant quantities during the survey. The ratio of the three slag types differed from slag heap to slag heap; unfortunately, time restrictions prohibited a detailed mapping of ratios and preference areas for individual types. A forth, and much rarer, morphological type was formed by very regular rods of slag, up to 10 cm long and about 2 cm in diameter. Their surfaces are rough, showing impressions and adhering fragments of ceramic. Their internal structure is usually made up from consecutive flows. Rare pieces were found still sitting inside tuyeres, clearly demonstrating the origin for all of them.

The picture becomes much more complex as soon as one digs a few centimetres into the slag heaps. Here a matrix of red, crumbly material of partly fired clay dominates with intermittent layers of ashy material and frequent fragments of tuyeres and furnace wall fragments. The content of slag in the interior of slag mound NW1 was found to be only about 40 wt% on average. The internal texture of this mound was found to be similar to the spoil heaps of the excavation, with sequential lens-shaped interlocking layers of different compositions. Even the accumulation of larger lumps of dense slag, regularly observed tumbling down the slope of the modern redim heaps and concentrating at their feet, was found in the ancient slag heaps. Apparently, this texture represent the dumping of different loads of waste during the build-up of the mound. In addition to the matrix of more or less fired clay and ceramic debris, the interior of the slag heap contained also a significantly higher content of smaller and more fragile slag fragments than the surface survey had indicated, including teardrops and aggregates of long, thin fingers, resulting in a higher proportion of non diagnostic material, i.e. slags which could not be assigned unambiguously to either smelting or smithing. Among this material were also several nut-sized pieces of corroded iron metal.

The metallurgical ceramic falls into two basic groups, furnace walls and tuyeres. The former was very badly preserved, and mostly restricted to remains a few centimetres thick adhering to the white-speckled furnace slag. Heat penetration into the furnace wall was obviously not sufficiently high to fire the furnace wall and to transform the clay of the wall into a more stable ceramic. The tuyere fragments, in contrast showed a much better preservation, and a very distinct gradient of heat impact along there length. The mouth pieces, slightly protruding through the white speckled furnace slag, were typically fused and black at their very tip, and bright red at those parts where they must have been within the furnace walls. The back ends, however, were always crumbling, and not a single piece with an original end preserved was found. Obviously, they were used in an unfired state and only burnt to ceramic during use where the heat was sufficiently high. It was also from within the slag heaps that frequently tuyere fragments were found completely filled with slag.

There was a consistent, though rather limited amount of non-technical debris among the excavated slag heap material. It consisted mostly of fragments of domestic pottery and isolated objects of stone and faience. As far as a chronological identification of this material was possible, it belonged to the late Meroitic period.

The analyses

A range of samples of slags and ores were returned to Bochum for chemical analysis by X-ray fluorescence and mineralogical study of thin and polished sections using polarised light optical and secondary electron microscopy.

The slags have a relatively high content of the oxides of aluminium (on average 6.6 wt%) and titanium (0.8 wt%), and a low concentration of alkali oxides (Tab. 1, Na_2O consistently below 0.1% and thus not given in the table). The dominating components are, as in all bloomery slags, silica (30.9 wt%) and iron oxide (57.2 wt%). The average concentrations of calcium oxide and manganese oxide are 2 wt% and 1.7 wt%, respectively. The combined (FeO+MnO) concentration of just below 60 wt% is extremely low when compared to typical European bloomery slags which typically have up to 70 and even 75 wt% of combined iron and manganese oxide (e.g. Oelsen & Schürmann 1954). The Meroitic slags thus cover the very iron-poor end of the distribution field for bloomery slag compositions, indicating a very efficient smelting technology.

The analysed ore samples are a random selection of the survey material collected from the surface. The low totals of the analyses (Tab. 2, on average 86.1 wt%, compared to 100.9 wt% for the slags) are believed to be mostly due to the mineralogy of the ore, with Fe_2O_3, FeOOH and $FeCO_3$ as the dominating iron compounds, while the analyses give the iron content as FeO to facilitate comparison with the slag analyses. The additional oxygen, hydrogen and carbon present in the ore minerals is driven off during the early stages of the smelting process, and does not enter into the slag. Therefore, one has to normalise the ore data to 100 wt% to get the effective iron oxide content of the ore. This gives for the two most iron-rich ores iron oxide concentrations of 68 and 78 wt%, i.e. well above the average iron oxide concentration of the slags and therefore totally suitable for smelting.

The microscopy of the slags confirmed the information obtained from the chemical analyses. The dominant phase in all sections is fayalite, Fe_2SiO_4, with hercynite ($FeAl_2O_4$) and

Table 1: Slag analysises from Meroe

Nr	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	K_2O	P_2O_5	Summe
2-1	29,5	0,6	6,7	58,6	1,0	0,5	1,7	0,1	1,0	99,6
2-2	33,9	1,1	8,1	53,1	1,1	0,6	2,1	0,2	1,0	101,2
2-3	26,8	0,9	6,5	62,3	2,3	0,5	2,2	0,3	1,0	102,8
2-4	32,3	0,9	6,8	55,9	1,3	0,5	2,7	0,2	1,0	101,6
2-5	32,5	0,9	7,9	55,3	1,4	0,5	2,5	0,2	1,2	102,4
2-6	31,9	0,8	5,7	52,1	3,3	0,5	1,9	0,2	1,0	97,4
2-7	28,4	0,9	6,7	60,7	2,1	0,5	1,7	0,2	1,1	102,3
2-8	25,2	0,6	4,6	64,9	1,0	0,5	1,2	0,1	1,0	99,1
2-9	37,6	0,3	6,2	51,7	1,4	0,7	2,4	0,3	0,9	101,5

Tab. 1: X-ray fluorescence analyses of slags from Meroe, Sudan. The concentrations for iron oxide and potash are surprisingly low when compared to Old World slags, while alumina and titania are significantly higher.

Table 2: Ores of Meroe

Nr	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	K_2O	P_2O_5	Summe
2-11	19,3	0,6	6,4	59,9	0,03	0,1	0,2	0,1	0,7	87,3
2-12	10,0	0,3	6,4	66,4	0,5	0,2	0,2	0,02	0,3	84,3
2-13	33,4	0,6	4,7	45,6	0,2	0,2	0,3	0,2	0,5	85,7
2-14	44,4	0,6	3,4	38,5	0,02	0,2	0,2	0,01	0,1	87,4
2-15	26,7	0,7	8,0	49,5	0,1	0,1	0,2	0,1	0,3	85,7

Tab. 2: X-ray fluorescence analyses of ore samples from the vicinity of Meroe, Sudan. The low totals are due to high amounts of iron hydroxide, carbonate, and trivalent iron oxide. The first two samples would be suitable for smelting without further processing. Note the relatively high concentrations of alumina and titania in these ores, linking them to the slag analyses.

interstitial glass as minor components. The amount of wüstite, free FeO, is very limited, and often the sections contain no wüstite at all. Hercynite is the main carrier of alumina, and its occurrence reflects the relatively high content of alumina found in the chemical analysis. In more potash-rich slags one would expect to find kalsilite ($KAlSiO_6$) or related phases instead, but with twenty times as much alumina than potash in the bulk analysis the absence of kalsilite is no surprise. The small amount of alkalis that is present is absorbed by the glass phase, as is the majority of calcium and phosphorous oxide.

The study of the heavily corroded metal fragments proved to be highly interesting. They all consist of grey cast iron with a considerable quantity of free graphite flakes distributed in a dense iron metal matrix that at some time obviously was liquid. It is unlikely that these fragments represent exactly the typical composition of the metal smelted at Meroe; it is rather quite possible that they are debris deliberately discarded as unusable by the ancient blacksmiths. And indeed, blooms are increasingly known to contain localised areas of considerably different carbon content in the metal, from almost carbon-free, ferritic, wrought iron through steel and up to grey and white cast iron. There are, however, good reasons to assume for Meroe a generally high average carbon content of the smelted blooms. One is the very low content of total FeO in the slag and the almost complete lack of free FeO, wüstite. This indicates severely reducing conditions throughout the smelts, resulting not only in a low remaining FeO concentration, but also in a high carbon metal. Another indication is the frequent occurrence of high carbon areas in the centre of Meroitic iron objects, while their surfaces are ferritic, and also at places where there are no apparent functional reasons to use steel rather than wrought iron (Rehren 1996). This combined evidence points to a generally high carbon content of the Meroitic blooms, at least for those which are related to the late Meroitic slags studied.

Interpretation

The limited evidence presented here allows to tentatively reconstruct a late Meroitic iron smelting scenario. A local ore which was relatively rich in aluminium oxide was smelted in tap furnaces with a shaft of at least half a metre height. The internal furnace wall was lined with a sand-rich layer up to the tuyeres, if not higher. Tapping was through relatively narrow holes, of about one or two centimetres diameter only, and often incomplete as the tuyeres were frequently blocked by liquid slag. The internal diameter of the tuyeres, of about 2 centimetres, indicates that there were bellows. The ratio of carbon monoxide to carbon dioxide in the reaction zone of the furnaces was much higher than in most European iron furnaces, resulting in the almost complete reduction of all the free iron oxide, and an accordingly high yield of metal. This metal was by all likelihood rich in steel, and may have had a fair amount of liquid or pig iron in it.

There are, however, many questions still to be answered. Were all the locally available ore types smelted, or was a particular type preferred? How much ore was smelted in each furnace, and how many smelts were made with each furnace? What was the typical iron content of the smelted ore, and how much iron metal was therefore produced per unit of slag? This latter question is crucial for the transposition of slag weight to metal produced; if we assume a typical FeO content of about 75 wt%, as indicated by the ores analysed, and 60 wt% FeO in the remaining slag, than exactly half of the iron in the ore would come out as iron metal. If, however, the FeO content of the ore was higher, say 80 or 90 wt%, than 67 or even 80 percent of the entire iron content of the ore would have been smelted to metal. A conservative estimate of a yield of 50 percent only, i.e. assuming 75 wt% FeO in the ore and extracting half of that amount as metal, would produce just short of 50 kg metal per 100 kg of slag. 10.000 tons of slag would thus represent about 5.000 tons of iron metal. This impressive figure, however, has to be broken down to an annual production; assuming that these 10.000 tons of slag were produced over 500 years at a constant annual rate would bring it down to 10 tons of raw metal per year. A further considerable reduction in this figure has to be made to allow for the inevitable loss of metal during the smithing of the bloom to a finished object. According to Crew (1992), this loss can be in the range of half the primary metal, leaving us with a estimated production of five tons of metal objects per year. To finish these theoretical mass balance calculations, a yield of 80 percent, obtained from an ore with 90 wt% FeO, would result in the production of about four times as much metal per weight unit slag, or about 20 tons of iron objects per year. An annual metal output in the order of about ten tons would certainly not justify the claim that Meroe was the 'Birmingham of Africa'.

This rather gloomy conclusion has, however, to be qualified. For one, the mass estimation survey of slag was confined to the fenced core area of Meroe, and several major slag heaps do exist east of this area. Then, although some allowance for the subsurface fraction of the measured slag heaps was included in the geometric formula, there is a good chance that this subsurface part is considerably larger than anticipated, and that several slag heaps are now totally covered by sand, and thus did not contribute to the estimate at all. Furthermore, one should note that there seems to be a whole series of substantial slag heaps in the wider region, following the fertile strip at both banks of the Nile like a gigantic string of black pearls. Finally, the even dispersion of the total metal production over a period of 500 years is purely arbitrary; reducing it to a shorter period of production would increase the annual output accordingly. In the absence of any regional survey and the lack of useable chronological indications about the length of the active period of iron smelting in Meroe, there is no way to even guess how much metal was really produced in the region per year.

Meroe, iron and Africa

What, now, does all this mean for Africa? One central question is still whether iron technology penetrated sub-Saharan Africa from the North, or whether it is an indigenous development. The current picture available from radiocarbon dates gives no clear answer to this, with similar, and similarly disputable, dates in the first half of the first millennium BC for several sites throughout Central and West Africa. Again: a detailed review of this aspect is not intended here, but the fact should be noted. We have, therefore, to revert to indirect evidence and arguments. In this context it seems to be significant that there appears to emerge from recent archaeometallurgical research in various parts of Africa a general tendency to suggest that an 'African' iron smelting furnace is more likely to produce a primary high-carbon bloom than a contemporary European iron furnace. Of course, there is a considerable overlap in the data, and pure ferritic iron was smelted in Africa as well as steel in Europe. The consistency with which this steel smelting seems to occur in Meroe, however, could suggest an 'African' rather than Northern origin for the related technology. In the same direction points the extreme scarcity of any evidence for iron smelting in Egypt during the first millennium BC and the early centuries AD. This makes it at least unlikely that of all countries Egypt was the transmitter for this technology into Africa.

But yet again, these arguments have to be qualified. The analytical data indicating the steel smelting was gained from surface material or material from very close to the surface, which according to the small finds which came with the analysed slags dates to the late Meroitic period. By then, an iron technology introduced more than half a millennium earlier may well have become 'Africanised', responding to the environmental and cultural conditions prevailing then at Meroe. Similarly, Egypt could have organised, or at least stimulated, the large scale surplus production at its southern fringes to satisfy a demand which it could not cover herself. This latter hypothetical option has to be seen in the context of two further questions: Why is this large iron-producing region situated where it is, and where have all those tons of iron gone? The Meroitic material culture is astonishingly poor in iron objects, and only recently has Lenoble identified the first significant number of large iron objects in a Meroitic context (Lenoble pers. comm., and Lenoble & Sharif 1992).

Why Meroe?

The necessary prerequisites for a flourishing iron industry are sufficient supplies of raw materials, particularly good iron ore, charcoal as a fuel and suitable clays to build the furnaces. At least as important are however the human resources, i.e. the necessary manpower and knowledge to do it, and the infrastructure and markets to absorb the products. All these factors seem to be at Meroe, or can be hypothesised.

Even today, the archaeological site of Meroe is covered by a dense cover of acacia trees, at least in its fenced part. Allowing for the considerably more humid conditions in that region two millennia ago, there is a good chance that it provided enough trees to sustain a specialised, charcoal-consuming industry over a considerable length of time. The ample supply of iron ores, with deposits worth their name even by modern standards (Schwarz 1992), has been mentioned already. The banks of the Nile, finally, provide enough clay to build the furnaces, and the internal lining of the furnaces with quartz sand makes up for the notoriously limited refractory properties of this clay. The environmental factors are there, and certainly in much more substantial quantities than anywhere in Egypt, except for the supply of Nile mud. Egypt could, however, well have provided the market to absorb the iron produced. Egypt's lack of iron smelting slags has been mentioned already, while iron objects, albeit late, do occur in her material record. The manpower and knowledge to smelt iron could well have been purely Meroitic, and in essence sub-Saharan. It would be interesting to investigate the organisational skills and / or the incentive to smelt all this iron as a surplus commodity and to ship it down the Nile in the context of the rule of the Nubian Pharaohs of the 25th dynasty, and the subsequent relationship of Egypt and Nubia. Did the quantity and quality of iron and steel available help the Nubians to seize power over Egypt, as it had helped the Hethites half a millennium earlier to declare themselves the winner of the battle of Kadesh (albeit disputed by Ramesses the Great)? Or was it a tribute paid to the Egyptians and could they once again despise the 'miserable Kush' after expelling the black Pharaohs?

Conclusion

The iron technology as practised at Meroe presents itself as an interesting piece of archaeometallurgical research, with ample opportunities to indulge in detailed chemical and mineralogical studies. Most urgently needed would be a technological study of the earliest phases of Meroitic iron smelting, together with firm dating of these earliest phases. The main questions, however, can only be tackled, and possibly solved, through ambitious archaeological fieldwork in and around Meroe, and a comprehensive study of a much wider range of arguments and materials involved. It appears obvious that not only an understanding of the relation of Meroe to sub-Saharan Africa is a matter of importance, but also that of Meroe and Egypt during the first millennium BC and well into the first centuries AD (see Expedition 35/2, 1993 for several papers on this aspect). Not for nothing did Meroe claim to maintain 'diplomatic contacts' at some time with Rome, on an 'equal' level. And yet another direction to look, not only for Meroe, but for Central Africa, is eastward: India boosts an early, and allegedly independent, iron technology, and early contact between India and the east African coast might have contributed to the spread and development of iron technology in Africa.

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