Sourcing the ore from the Drierivier copper smelting site in central Namibia, using lead isotope fingerprinting

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COPPER SMELTING RESIDUES FROM *c.* AD 1650 found at the Drierivier site near Rehoboth in central Namibia have ^{207}Pb/^{206}Pb isotope ratios that match a particular deposit at Swartmodder, but are markedly different from other known occurrences in the Rehoboth–Windhoek areas. For this reason, precise lead isotope determination is not necessary to source the ore, and raw peak height ratios obtained by inductively coupled plasma mass spectrometry are sufficient. This characteristic signature is present in all samples of malachite ore, slag, and copper prills collected on the site. Significantly, it is absent from a sample of local native copper, as well as from seven copper beads found elsewhere in central Namibia. This not only identifies the probable source of malachite ore but also provides a powerful tool for provenancing copper artefacts made at the Drierivier site, distinguishing them from those made elsewhere in the Namibian highlands.

Geological and geomorphological context

The Drierivier copper smelting site (23°22′S, 17°12′E) is located a few kilometres south of the town of Rehoboth in central Namibia. The site is situated on the broad floodplain of the Oanob river, some 5 km east of a range of low hills which contain outcrops of malachite ore at the abandoned modern mine at Swartmodder.[1] The local geology is very varied. It forms part of the Rehoboth Basement Inlier (Fig. 1). This arcuate outcrop of Proterozoic metasedimentary and igneous rocks is sandwiched tectonically between the Damara Group (late Precambrian metasedimentary rocks) and the Nama Group (largely unmetamorphosed sedimentary rocks of late Precambrian/early Cambrian age). The Rehoboth Basement Inlier is a fragment of Proterozoic crust which has a wide range of published radiometric ages, from about 1 to 2.4 Gyr ago.[2,3] It is locally richly mineralized and hosts numerous small copper sulphide bodies which are the sites of a number of small, now-defunct modern mines.[4]

Archaeological context

The migration of Bantu-speaking peoples into southern Africa brought an agricultural iron- and copper-producing society to the subcontinent in the late first millennium BC.[5] The population density might not have been high enough to force expansion into marginal environments like the dry and barren uplands of central Namibia. Thus, it is reasonable to accept that the inhabitants of central Namibia at the time of the first European explorations were pastoral nomads whose society evolved from the preceding hunter-gatherer culture, perhaps under the cultural influence of the Bantu immigrations.[6]

When the first European explorers arrived in the 18th century, they found copper goods in the coastal area but no knowledge of metal working. They were told of ore bodies and itinerant metal smiths who dwelt in the central highlands. These smiths were said to trade their wares periodically for livestock,[7] and the presence of stock pens near several of their metal-working sites bears out this report. Modern excavations have revealed several smelting sites on the central plateau, which have been radiocarbon dated to between the 15th and 19th centuries.[8] These smelting sites probably were a result of cultural diffusion from the surrounding Iron Age cultures, but in central Namibia a unique stone-based smelting technology was used, which points to local innovation or adaptation.[1]

Metal artefacts have been found as burial goods at various sites in Namibia, but it is not known what proportion of this metal was locally produced and what proportion was obtained by trade.[6,7] If it can be shown that a significant part of it

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was locally produced, the importance of the itinerant smiths in the Namibian highlands would be emphasized. Their evolution of a smelting tradition using stone rather than the usual clay for furnaces and tuyères is of wider archaeological significance because it negates any assumption that possession of clay ceramic technology is a necessary precursor to metals production.

The Drierivier copper smelting site

The copper smelting site at Drierivier consists of a pit about 2 m in diameter, surrounded within 30 m by twelve metal-working stations, with associated scatters of slag, charcoal, and stone, including fragments of bored-stone tuyères.[1,9] Originally thought to be an iron smelting site,[10] subsequent more detailed excavation and metallographic analysis revealed metallic copper slag inclusions and copper prills which identify it as a place of copper smelting.[1] Radiocarbon dating gave an average calibrated age of about AD 1650 on two pieces of charcoal,[1,10] although this might reflect the use of old wood.

The location of the site seems to have taken advantage of the natural resources needed to produce copper with a wholly stone technology. The river bed of the nearby Oanob river provided quartzite cobbles for hammer stones and an adjacent diorite outcrop supplied anvil stones for releasing copper prills or solidified droplets by crushing the slag.[1] An adjacent stand of old-growth *Acacia erioloba* is the probable source of fuel, as the charcoal is from an *Acacia* species (E. February, University of Cape Town, pers. comm.). While there is no deposit of malachite (a green, hydrated copper carbonate) in the immediate vicinity, there are several known ore bodies within a few kilometres of the site.[1] The high grade of these oxide ores would have made transportation a minor factor.[7]

To characterize the smelting technology used, prills and slag from the site were analysed metallographically and using energy dispersive X-ray fluorescence.[1] Iron smelting was ruled out because of metallic copper inclusions in the slag. The high fayalite (iron silicate) and magnetite (iron oxide) content of the slag was not necessarily an indication either that iron was smelted or that iron oxide was added as a flux.[11] The possibility that sulphide ores had been roasted to oxides before smelting was not considered likely as ample high-quality oxide ores were available in nearby surface deposits and discarded fragments of malachite were found on the site. Thus we concluded that the metal working consisted of charcoal reduction of high-quality copper oxide ores in a pit furnace. The forced draught of air was supplied via stone tuyères with holes drilled through them, of which a number of examples were recovered in the excavation.[1,9] There was no evidence for remelting of copper prills in ceramic or stone crucibles, and presumably the product was reworked directly into small artefacts.

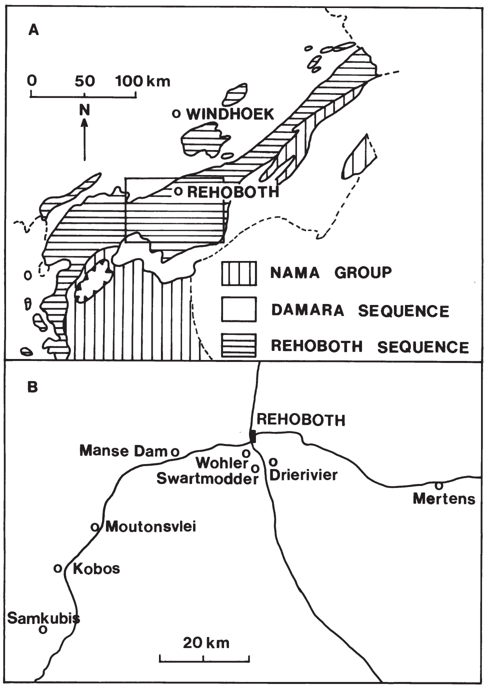

Fig. 1. A, Geological sketch map of the Rehoboth area, showing the Proterozoic Rehoboth Basement Inlier tectonically sandwiched between the Damara Sequence (late Precambrian) and partly covered by the late Precambrian to early Cambrian Nama Group. **B**, Sketch map showing the location of malachite sampling sites within the Rehoboth Basement Inlier.

Aside from the unique smelting technology employed, the interest in the site lay in the fact that all the different phases of the smelting process were represented in good association. The lead isotope composition of local wood, malachite ore nodules from the site, slag, and copper prills was determined as part of a student project at Harvard University, and all but the wood showed distinctive low ^{207}Pb/^{206}Pb ratios.[12] This implied that the source of the ore used at Drierivier could be identified by this isotopic ratio.

Archaeological provenancing using lead isotopes

The variability in lead isotope ratios in nature provides a provenancing criterion to supplement or replace conventional trace element chemistry.[13] Lead isotope data have been employed principally in the Mediterranean region to determine the provenances of various silver and bronze artefacts from historical times. Because of difficulties with experimental technique and the statistical interpretation of the data, the published results have been much criticized.[14] Nevertheless, initial scans of samples from the Drierivier site showed such a distinctive signature that it was thought that lead isotope analysis of these samples would not be complicated by the problems associated with more subtle isotopic signatures.

Geological samples of malachite and native copper from localities ranging from the Kaokoveld in northern Namibia to Namaqualand in northwestern South Africa were analysed to provide a comparative background, with a concentration of samples taken from malachite sources within the Rehoboth Basement Inlier (Fig. 1). All the geological samples were analysed blind, without the analysts' (Young and Green) knowing their geographical relation to the Drierivier site. The archaeological samples analysed consisted of three pieces of local *Acacia* wood; fourteen samples of slag, four copper prills, thirteen pieces of malachite, and ore matrix from scatters on the Drierivier site; as well as seven copper beads from three other sites in central Namibia previously subjected to detailed metallographic examination and chemical analysis by energy dispersive X-ray fluorescence.[15]

Some of the samples were analysed on the Fisons VG PlasmaQuad II/s inductively coupled plasma-mass spectrometer (ICP-MS) in the Department of Geology and Geophysics at the University of Hawaii, using standard wet chemistry preparation techniques.[16] Each sample was run ten times and the results averaged. Other samples were analysed by laser ablation-ICP-MS on the VG PQ II+

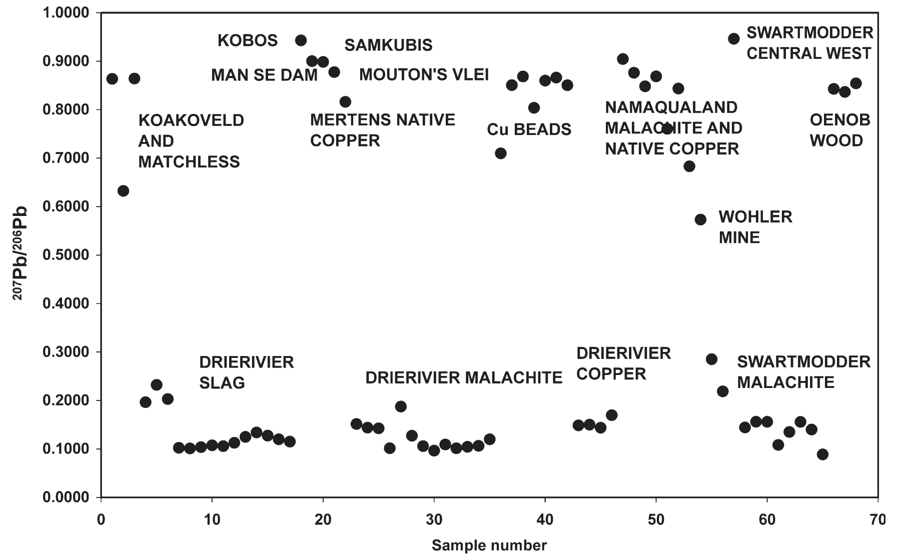

Fig. 2. Plot of lead isotope ratios (^{207}Pb/^{206}Pb) showing the close correspondence between material from the Drierivier copper smelting site and malachite from the Swartmodder ore body.

ICP-MS at Harvard University. Because the Drierivier samples had such distinctive lead isotope ratios, only raw peak height ratios were recorded, as previously done in a similar exploratory fingerprinting study of South African archaeological gold.[17]

Results

The isotopic results are illustrated in Fig. 2, with the ^{207}Pb/^{206}Pb ratio plotted for each sample. All the Drierivier malachite, slag and copper prill samples displayed low ^{207}Pb/^{206}Pb ratios, as did all but one of the malachite samples from the vicinity of the Swartmodder ore body. The Oanob wood, the seven copper beads from central Namibia, and all the other geological samples including the Mertens native copper displayed distinctly higher ^{207}Pb/^{206}Pb ratios (Fig. 2). These results clearly identify the Swartmodder copper body as the most likely source of the copper ore smelted at Drierivier, and would provide an effective tool for tracing any material produced there. The seven copper beads from central Namibia had lead isotope signatures quite distinct from the Drierivier material and could not have been manufactured there. Their geological source cannot be identified from these data because their lead isotope signatures were consistent with a number of the other central Namibian sources of copper (Fig. 2). The highly distinct ^{207}Pb/^{206}Pb ratio of the Swartmodder malachite made it possible to characterize this ore source and answer the archaeological question economically, without having to resort to more precise and expensive measurement of all the lead isotope concentrations in these materials. What remains unexplained is the geochemical reason for the anomalous lead isotope ratios for most of the Swartmodder ore body, but that is a geochemical question beyond the scope of this enquiry.

Conclusions

The Swartmodder copper ore body was identified as the most likely source of malachite smelted at the Drierivier site. This was based on the extremely unusual lead isotope ratios in this ore. The resulting products, slag and copper prills reflected the malachite ore lead isotope composition. Reworking native copper found some 15 km distant could be excluded on the basis of its distinctive lead isotope signature; it definitely was not processed at the Drierivier site.

This lead isotope study could not determine the geological source of seven copper beads recovered from a number of sites in central Namibia because their isotopic signatures were not sufficiently distinct from those of several central Namibian sources sampled. Nevertheless, the seven beads were not made from copper produced at Drierivier using ore from Swartmodder. Lead isotope sourcing of these and other beads from Namibian sites would require greater precision in analysis than achieved in this study. The success of employing ICP-MS determination of the ^{207}Pb/^{206}Pb isotope ratios in identifying Swartmodder as the probable source of malachite for the Drierivier copper smelter lay in the highly unusual lead isotope ratios for most of the Swartmodder ore body. These could be a useful tool in tracing metal manufactured at the Drierivier site, if such material were recovered in future excavations in the Rehoboth area or farther afield. This, in turn, may provide further information about the itinerant pastoral smiths who are assumed to represent a unique metallurgical tradition based in central Namibia. This sourcing study shows that the scale of analysis should be matched to the complexity of the problem, and that in appropriate circumstances even relatively imprecise analysis can provide useful data for archaeological interpretation.

We acknowledge the assistance of Rehoboth Museum, K.B. Siebeck (former mine engineer at Swartmodder mine) and H. Dentlinger (Rehoboth) in the collection of malachite samples in the Rehoboth area. R. Pflaum provided invaluable technical guidance in the operation of the ICP-MS at the University of Hawaii. We thank I. Horn (Swiss Federal Institute of Technology) for assistance in developing the laser ablation-ICP-MS analytical protocol used. Financial support from Anglo American Chairman's Fund, De Beers Educational Trust, and the National Research Foundation for archaeometallurgical research at the University of Cape Town is acknowledged with gratitude. Opinions expressed in this paper and conclusions arrived at are those of the authors and are not necessarily to be attributed to any of the supporting agencies.

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