Trace-element study of gold from southern African archaeological sites

The history of gold mining and its fabrication into jewellery and other items of adornment goes back at least 1000 years in southern Africa. Trace-element analysis of gold artefacts from the major archaeological sites of Mapungubwe, Bosutswe and Thulamela has led to fascinating insights, and an expansion of this analytical programme to seek answers to archaeological questions previously inaccessible to science.

Gold is frequently found in early second millennium AD archaeological assemblages in southern Africa. It was used exclusively for personal adornment and insignia, and most of it has been recovered from excavations of elite burial sites. The famous gold jewellery and ornamental objects from 10th to 13th century AD Mapungubwe and 13th to 15th century AD Great Zimbabwe have been studied non-destructively and described as the products of typically African fabrication technology.1,2 Metallographic investigation has shown that the fabrication techniques were identical to those used for making similar copper items.

Evidence for gold processing is widespread, but excavations at only two sites, Great Zimbabwe and the 16th-century AD site of Thulamela (Fig. 1) in the northern Kruger National Park, South Africa, have produced evidence of smelting operations in the form of indigenous ceramic sherds that had been used as gold-melting crucibles and had adhering glassy slag containing gold droplets.3,4

Recently, the archaeological focus has been on the trace-element chemistry of gold from these sites.5 Over one hundred individual gold objects from four sites (Mapungubwe, Bosutswe, Great Zimbabwe and Thulamela) have been analysed by laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS), their trace element profiles grouped, and compared with each other and reference material. The samples from any one site have distinctive patterns (or sets of patterns), which usually are unique, with the exception of one case where two sites have overlapping patterns. This pointed to distinct geological sources of the gold, with minimal mixing of material from discrete origins. The relatively high levels of platinum-group metals are characteristic of southern African gold, uncommon in material from elsewhere tested at Anglo American Research Laboratories.

Given the likelihood of some degree of mixture, and the paucity of well-provenanced historical alluvial samples, it is unlikely that trace-element sourcing will be able to identify distinct archaeological origins. Current research is directed at attempting to define regional comparative signatures in order to distinguish archaeological material derived from the various geological provinces of southern Africa.

The archaeological sites
Scattered across central southern Africa, in a broad band that includes the Zoutpansberg, the Limpopo Valley, eastern Botswana, and southern Zimbabwe, lie archaeological sites representing the former residences of elite chieftainships. These formed part of an interwoven social structure of metal-using farmers who occupied large parts of southern Africa from nearly two thousand years ago.6 In the first millennium AD, local indigenous farming communities produced copper and iron for their own use in jewellery and utilitarian implements. In the second half of the first millennium, the southern African farming communities became increasingly involved in the Indian Ocean trade network, exporting various commodities through Arab middlemen in exchange for glass beads and cloth. Metal was an important export commodity, and around the beginning of the second millennium AD both gold and tin were added to the list of metals being mined in southern Africa.7

Trade benefited powerful chiefs, whose residences were strategically placed near the river valleys that provided access to the coast. They accumulated wealth and status, moved to occupy symbolically elevated and more readily defensible hilltop sites, and their residences became the centres of the first real southern African towns.8

Mapungubwe was an early example of such a town, dating from the 10th to the 13th centuries AD, situated in South Africa just south of the confluence of the Limpopo and Sashi rivers.

Towards the end of the main period of occupation at Mapungubwe, particularly wealthy and presumably powerful individuals were buried in graves on top of Mapungubwe hill.6 In January 1933, exploration of the northwestern end of the hilltop led to the discovery of gold beads, helically wound gold bangles, decorative gold sheet perforated with holes for small tacks, and the parts of a rhinoceros made of gold sheet, all loose and near the surface.9,10 A nearby grave was found, probably that of a man, with a

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Fig. 1. The archaeological site of Thulamela in the northern Kruger National Park, with the partially reconstructed stonewalling of the royal enclosure.
large number of corroded iron bangles ornamented with gold and glass beads around the arms and legs, about 130 helically wound gold wire bangles around the arms and neck, fragments of gold sheet (possibly from a head rest), golden sheeting that may have covered a wooden bowl, a hollow gold bangle, a gold ornamental circlet and pointed sheath of a staff, and quantities of loose gold and glass beads. The gold found was reported to have weighed about 2.3 kg (75 ounces) in total.9

In the summer of 1934/35, archaeologists from the University of Pretoria excavated the grave of a woman with iron wire arm and leg bracelets, on Mapungubwe hill. This was followed by the discovery of an entire graveyard on the western end of the hilltop, where 23 more burials were found. Two of these contained gold. One was that of a man buried facing west, with a gold ‘sceptre’ (probably part of a staff) in the crook of the right arm and 100 small gold beads from a disintegrated necklace. The other contained presumably a woman, buried with approximately 2 kg of gold. She was also buried facing west, with over 100 gold coiled-wire bangles around her legs, pieces of gold plating possibly from a head rest, and 12 000 gold beads around her neck, as well as a very large number of glass beads. The exciting story of these discoveries was published in 1937 by Professor Leo Fouché.9

The discovery of such large quantities of gold in only three burials, dating from 800 years ago, fuelled intense speculation for the past 50 years. South African archaeologists believe this gold and the gold found farther north in modern Zimbabwe was mined locally, but some believe that this gold was imported, perhaps even from India. We sought confirmation of the suspected indigenous source of this gold, but until recently it was not even theoretically possible to determine this.

At approximately the same time as Mapungubwe was occupied, other hilltop settlements were thriving elsewhere. The archaeological site of Bosutswe in modern eastern Botswana was one of these. Here too people were involved in trade networks, even at a significant distance from the Limpopo corridor to the coast. In the 1980s, archaeologists James Denbow and Edwin Wilmsen from the University of Texas excavated parts of the site. In layers with characteristic pottery similar to that from Mapungubwe, they came across a small helix made of gold. This must have been part of a bangle or other jewellery ornament, but is the only fragment of gold recovered from Bosutswe. We would like to know if this fragment came from Mapungubwe or whether the people living at Bosutswe had access to another source of gold.

Gold has been recovered from numerous other sites in southern Africa, including the famous stone-walled trading centre at the site of Great Zimbabwe, but few of these have been excavated professionally by archaeologists. The 16th-century AD site of Thulamela in the northern Kruger National Park is an exception. It was excavated in the mid-1990s by a team led by Sidney Miller, and the gold from it forms only the second substantial South African gold assemblage studied scientifically. A few gold beads, nodules, wire, and fragments of helically wound wire bangles (Fig. 2) were found in the excavation of a midden, or rubbish dump, associated with stone-walled ruins on top of Thulamela hill. This discovery was accompanied by the recovery of several fragments of indigenous pottery with adhering lumps of glassy slag with entrapped droplets of gold, direct evidence of gold working in the hilltop settlement. Towards the end of the last season of excavation, Miller discovered two graves on the hilltop. The first was a woman, buried facing west and lying on her side, with a plaited gold bangle around one wrist and a string of 291 gold beads around her neck. Nearby was the grave of a man, adorned with a now very corroded iron necklace ornamented with a multitude of gold clips. This burial also included a number of gold bangles and fragments of gold sheeting with gold tacks (Fig. 3) that must have been attached to a soft base like a wooden bowl or head-rest, now completely decayed.

The gold recovered from Thulamela can be compared directly with that from Mapungubwe, although they are some
200 km apart and at least three hundred years separates the occupation of the two sites. Did the gold from Thulamela and Mapungubwe come from similar or different sources, and did the inhabitants of each site have access to only one or multiple sources of gold?

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**Gold fingerprinting technology**

Anglo American Research Laboratory’s fingerprinting technique to identify gold was originally intended to detect crime. Each year substantial amounts of gold stolen from South Africa’s gold mines are recovered by the police. The problem is to know to which mine any particular gold belongs and should be returned. The solution to the problem was the development of a technique for reading the unique fingerprint of gold from any particular source, and comparing the impurity profile of the recovered gold with those of all known sources on file. The fingerprint of any particular gold source is as individual as our faces. Even if the gold from a few different sources has been mixed, the match with the individual origins can be determined. In practice this means that stolen bullion can often be identified with the individual mine shaft from which the gold came.

In LA-ICP mass spectrometry, a gold object is placed in the sample chamber of the spectrometer and a powerful laser beam vaporizes a tiny amount of the metal, leaving a very small hole. The vaporized gold, with its trace-element impurities, is swept up by a stream of inert gas and injected into a very hot plasma flame which separates the individual atoms and ions. These are sucked into the spectrometer detection system, where each atomic particle is sorted according to its mass/charge ratio and a detector records the presence or absence of each of the 234 naturally occurring isotopes. This information is fed to a computer which can produce a graphical fingerprint for the sample and also can compare this with the known characteristics of gold from various sources, stored in its memory. If the gold is from one of the known sources which has already been fingerprinted, then there should be a match, with a reasonable degree of statistical probability.

This method is virtually non-destructive and valuable samples can be analysed this way, producing only minimal visible damage. The analysis does not seek to determine the absolute quantity of trace elements but only whether they are present or absent. It is simpler, quicker, and more reliable than other chemical analytical techniques because it does not depend on comparative analytical standards and complicated wet chemistry procedures to get the gold and all its impurities into solution.

There are additional advantages when investigating archaeological samples. Quite large objects can be placed in the laser chamber and the holes caused by the laser are tiny. If the object is positioned carefully, the holes can be made in an inconspicuous place so that the minute damage is not visible. The laser can also be used as a drill to bore through any surface layer that has become contaminated or corroded with the passage of time. This allows the analyst to sample the unaltered original gold in the body of the object.

**Analysis of archaeological materials**

The LA-ICP-MS technique was applied to over a hundred individual gold objects from the sites of Mapungubwe, Bosutswe, Great Zimbabwe and Thulamela. All the gold contained variable levels of silver and copper as significant
impurities. The fingerprints of the gold artefacts from Mapungubwe fell into at least two, and possibly three, groups, defined on the basis of the presence or absence of strontium, rare-earth elements, platinum-group elements, barium and mercury. All the Thulamela gold had signatures that were similar to that of one of the Mapungubwe groups, with strontium, rare-earth elements, platinum-group elements, barium and mercury present (Fig. 4). The single gold sample from Bosutswe had a signature that was distinct.

The lack of any systematic patterning in the copper and silver levels in the gold, with silver varying up to 10% by weight, showed that no refining had been practised. It also showed that deliberate alloying to control the physical properties of the metal had not been done. In the Middle East and India, gold refining and deliberate alloying have been practised since at least the first millennium AD. This is one line of evidence that the southern African gold was probably locally produced. Other evidence pointing to the local production of this gold was the presence of platinum-group metals as significant trace impurities. These relatively high levels are characteristic of southern African gold, and relatively uncommon in material originating elsewhere.

The fact that the trace element fingerprint signatures at Mapungubwe grouped so clearly points to geologically distinct sources of the gold. If the gold had come from one source, or if the material from a diversity of sources had been thoroughly mixed together then one would expect a general blur of results, without distinct grouping of the fingerprints. One of the implications of this is that the Bosutswe sample represents gold from a completely distinct source. Another implication is that the source of Thulamela gold may have been exploited much earlier by the people of Mapungubwe. This interpretation is strengthened by the lead isotope ratio profiles of the Mapungubwe and Thulamela gold, which are similar to each other and distinct from either the Bosutswe or the naturally occurring average.

Future research

The next step is to compare the trace element fingerprints of the artefacts from the three sites in more detail with signatures of gold from various other regions, such as North Africa, the Middle East and India. This may confirm whether southern African archaeological gold was locally produced. We must assemble appropriate comparative material from known sources before this can be done reliably. The next stage will be to identify which region of southern Africa provided the gold for specific sites. This may be somewhat easier because some of the comparative fingerprint data for reef and alluvial gold is at hand, although there are large gaps for some regions where there were early gold mines, such as Mozambique. Far more difficult would be the task of trying to match individual gold artefacts to specific local geological sources. It is possible to source modern gold very precisely only because comparative samples of modern source material are readily available. Archaeological gold was probably recovered from alluvial deposits or surface quartz veins worked out by early miners. Looking for specimens of gold found by past prospectors and now preserved in museums may be fruitful, and this line of enquiry is being pursued.

The fingerprinting of archaeological gold artefacts is a potentially rich source of information, despite the difficulties of locating contemporary comparative material. The LA-ICP mass spectrometer fingerprinting technique promises to enable archaeologists to unravel the history of gold production and trade at a level of detail unimaginable until very recently.

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