A Great Lakes pouch of black-dyed skin with porcupine quillwork: an update

Pippa Cruickshank

SUMMARY In 2009 the author, together with Vincent Daniels and Jonathan King, published an article on a rare black-dyed skin pouch with porcupine quillwork (British Museum 1937,0617.1) in an earlier volume of this Bulletin. Its publication has recently led to some exciting new developments, which are presented alongside a brief description of what is known of the history of this pouch from the Great Lakes since it was created in around 1755–1780.

In the early 1990s an album of 40 watercolour paintings by Sarah Stone of objects in the Leverian Museum was put up for sale. The Leverian Museum, Sir Ashton Lever’s Museum in London, was open from 1775 until 1786 before its contents were dispersed by sale in 1806. One of these watercolours depicts the late-eighteenth-century pouch from the Great Lakes that is the subject of this contribution and which was already in the British Museum collection at the time of the sale, Figure 1. It was this association that helped to enable the Museum to purchase the album. It is not known what happened to the pouch between c.1785 when it was painted by Sarah Stone and its arrival at the British Museum in 1937.

The skin of the pouch has degraded badly since it was depicted in the painting: the combination of iron and tannin in the black dye has accelerated the deterioration of the skin, leaving it very brittle, friable, powdery and prone to tearing. A 2009 article described a complex conservation treatment that was developed to reunite all the parts that were known to exist at that time [1; pp. 68–71]. The process included reversing a previous conservation treatment carried out by another conservator in the 1970s, as it was no longer helping to keep the

Figure 1. Watercolour painting (British Museum Am2006,Drg.53) of the pouch by Sarah Stone, c.1785
bag intact, followed by strengthening and infilling significant areas where the black-dyed skin was fragile or missing and rejoining the lid to the main body of the bag, Figure 2.

When compared with Sarah Stone’s watercolour, the most obvious parts absent were a brightly coloured quillwork strip on the pouch flap and the majority of the tassels hanging from the lower edge of the pouch. These had been missing since at least the 1970s when the pouch was first conserved for display in the British Museum exhibition Thunderbird and Lightning, held at the Museum of Mankind in 1982.

However, in 2014 a quillwork artist and private researcher living in North America rediscovered the quillwork strip that
and widely available. Finally, but not least, the publication of collaborative work at the British Museum by a conservator, scientist and curator in a journal with an international reach through free download, together with the dedicated and inspired work of a specialist researcher in North America, allowed the vital connection between these two dislocated objects to be made.

Author
Pippa Cruickshank (conservation@thebritishmuseum.ac.uk) was a conservator in the Department of Conservation and Scientific Research at the British Museum from 1977 to 2015.

Reference

Note
1. Eli Motsay belongs to the group of artists in North America known as ‘At the Eastern Door’ [http://attheeasterndoor.wix.com/attheeastern
door: accessed 29 March 2015] that is “dedicated to well researched and documented reproduction material culture of the 18th century”. Examples of his quillwork include several faithful reproductions of rare late-eighteenth-century black-dyed bags with native religious imagery in dyed porcupine quillwork [http://attheeasterndoor.wix.com/attheeasterndoors#zippers-by-johnny/claru7: accessed 29 March 2015].
A metallographic study of some debased silver coinage of Henry VIII

Quanyu Wang, Constantina Vlachou-Mogire, Megan Gooch and Barrie Cook

SUMMARY

The events of Henry VIII’s ‘Great Debasement’ are well recorded in historical documents and it has long been known that the coins contain high amounts of base metals, as Henry Symonds assayed 11 coins in the British Museum in the early twentieth century.

This research revisited 10 of those original 11 coins plus two additional coins that were sampled by Symonds but were not included in his report. In this current study optical microscopy, metallography and scanning electron microscopy with energy dispersive X-ray spectrometry were used to retest the metal compositions of the coins and also to investigate their methods of manufacture and surface plating techniques, which had not been examined previously.

All the coins examined comprise silver-copper alloys and appear to fall into three groups: one coin is made of sterling silver (a silver-copper alloy containing 92.5% silver), three contain c.50% silver and the remaining eight contain approximately one-third silver. These findings are in general agreement with Symonds’s data and are consistent with what is known of the debasement sequence in that period. Most of the coins showed severely elongated, silver-rich α phases in their microstructures, indicating that they were struck from a heavily hammered sheet of metal rather than from a cast blank. The silvery appearance of the coins containing c.50% silver was achieved by deliberate removal of copper from the surface metal prior to striking. The coins that contained approximately one-third silver showed evidence of surface silver enrichment and in some cases there seemed to be distinct traces of applied layers of silver plating. Analytical evidence for mercury in one coin suggested that silver amalgam plating was in use. This infers that undocumented plating techniques were used in the mints concurrently with other methods.

Introduction

In 1913 Henry Symonds was struggling with documentary evidence for the ‘Great Debasement’ of the sixteenth century. He combed mint indentures, exchequer accounts and other documentary sources for clues to identify the sequence of Henry VIII’s coin types [1]. Unusually, and bravely for the time, he also used the technique of cupellation (or fire assay) to test the purity and alloy composition of samples from 11 coins he bought for the British Museum for the purposes of scientific experimentation, Figure 1. Symonds compared the alloys of his sample coins to the standards indicated in the indentures and found the results inconclusive. The planning for the permanent exhibition Coins and Kings: The Royal Mint at the Tower, which opened at the Tower of London in 2013, provided the authors with an opportunity to retest these coins using modern scientific equipment and techniques, and to review the significance of the alloys within them.

The scale and legacy of the Great Debasement set it apart from other royal interferences into the coinage of the realm. Debasement was the reduction in the weight of coins, reduction in the precious metal content or the increase in the mint tariff while the coins remained superficially the same [2]. In the Great Debasement all three of these debasing practices were applied to the coins of Henry VIII and in the years immediately after his death in 1547.

The reduction of weight and fineness (precious metal content) is well attested in contemporaneous documents and the variations in mint tariffs have been carefully deduced by recent historians. Coins fresh from the mint often appeared to be made of good silver as they were ‘blanched’ in a weak acid to clean the factory grime from them before striking
and to increase the silver to copper ratio in the surface layer. While this form of surface enrichment produced a coin with a silvery appearance, during use the copper in the alloy began to show through the silver-rich surface, earning Henry VIII the nickname of ‘old copper nose’, since the copper showed through on the high relief in his portrait. Surface enrichment by blanching was nothing new in coin manufacturing, but it was the poor quality of the alloy in these coins that earned Henry his nickname and drew public attention. By the 1550s coins leaving the mint were so debased in fineness that the poor alloy was visible to those using the coins.

Except for a study of two unprovenanced coins of Henry VIII that were analysed by Bayley and White [3], there has been little evidence prior to this current study to suggest that the mints did anything other than implement the debasement plan by reducing the fineness of alloys, weight and mint tariff as required by mint indentures. These documentary sources have revealed certain corrupt practices during the debasement, especially under Sir William Sharnington at Bristol, but these were connected with irregularities in accounting and finance rather than the alteration of the material of the coins [4]. There is no documentary evidence to show that the moneys or other individuals within any of the mints were using methods other than those sanctioned by the king’s indentures to debase his currency. The present study set out to determine whether fresh analyses of a small sample of Henry VIII’s coins might reveal any new information about how mint workers met the increasingly difficult requirements of debasing the coins of the realm.

Analytical techniques
All the coins were examined using optical microscopy and scanning electron microscopy equipped with energy dispersive X-ray (SEM-EDX) spectrometry to investigate surface features, including possible surface plating. The SEM-EDX system used was a Hitachi S-3700N variable pressure SEM with an Oxford INCA Energy system. The samples were not coated and the analyses were run at an accelerating voltage of 20 kV in low vacuum (50 Pa) and with a working distance of 10 mm.

Cross-sections for the metallographic study were taken using an Isomet diamond saw after the surface analysis by SEM-EDX. Each section was chosen to cover recessed areas or grooves where surface plating (if originally present) is usually preserved. The sections were polished to a finish of 1 µm for SEM-EDX examination of both alloy compositions and surface plating techniques. All the SEM images presented here are backscattered electron images of the cross-sections. After compositional analysis, the polished sections were etched using an acidified potassium dichromate solution to reveal the metal microstructure.

Results and discussion
Surface examination
All the coins were examined under a stereomicroscope and a few showed sign of surface plating. These coins were subjected to different degrees of corrosion and wear, resulting in surface plating layers being lost in most places but preserved in some recessed areas. The surface of coin 1924,0707.9 was shinier than the other samples and surface analysis by SEM-EDX showed that mercury was present, indicating the use of silver amalgam. However, none of these surface differences were visible to the naked eye, meaning that coin users would not have been able to identify any differences in the production of their coins.

Metal composition
The metal compositions of the coins were determined by SEM-EDX and the results are presented in Table 1. The analysis was carried out on the metal core, away from surface enrichment/corrosion/plating layers, to determine the original metal composition. These coins can be classified into three groups based on their silver contents: coin 1924,0707.1 is of
A metallographic study of some debased silver coinage of Henry VIII

Sterling silver; coins 1924.0707.2, 11 and 12 contain 50–51% silver; and the remaining coins contain 33–35% silver. While the metal compositions obtained by SEM-EDX were generally consistent with Symonds’s assayed data [1], the new analyses provided further information. The two additional coins that were not studied by Symonds can be securely dated to 1549 and showed higher silver contents than would be expected from their late date. The SEM-EDX results also echoed the known sequence of debasement, starting with sterling silver before 1544, to 75% (9 oz) silver in 1544, half (6 oz) silver in 1545 and then one-third (4 oz) silver in 1546: a conversion between the silver content in ounces (oz) and weight percentage is given in the notes to Table 1. The coins that were analysed did not seem to include any displaying the first level of debasement, but represented the two later stages.

All the debased silver coins had a microstructure consisting of two phases; a copper-rich $\beta$ phase and a silver-rich $\alpha$ phase.

### Table 1. Alloy compositions of the coins of Henry VIII, determined using SEM-EDX analysis, together with the silver contents found by Symonds [1]. The results are normalized and given in weight percent (wt%).

<table>
<thead>
<tr>
<th>BM registration number</th>
<th>Symonds’s number</th>
<th>Symonds’s silver content [1]</th>
<th>Cu</th>
<th>Ag</th>
<th>Pb</th>
<th>As</th>
<th>Au</th>
<th>Al</th>
<th>Si</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1924.0707.1</td>
<td>1</td>
<td>91.46</td>
<td>7.3</td>
<td>91.2</td>
<td>0.8</td>
<td>nd</td>
<td>0.4</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>1924.0707.2</td>
<td>3</td>
<td>52.29</td>
<td>47.4</td>
<td>51.1</td>
<td>0.6</td>
<td>0.6</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>nd</td>
</tr>
<tr>
<td>1924.0707.3</td>
<td>4</td>
<td>41.67</td>
<td>64.5</td>
<td>34.0</td>
<td>0.4</td>
<td>0.4</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>1924.0707.4</td>
<td>5</td>
<td>36.88</td>
<td>64.7</td>
<td>33.9</td>
<td>0.6</td>
<td>0.6</td>
<td>nd</td>
<td>0.1</td>
<td>0.1</td>
<td>nd</td>
</tr>
<tr>
<td>1924.0707.5</td>
<td>6</td>
<td>35.42</td>
<td>63.4</td>
<td>35.0</td>
<td>0.5</td>
<td>0.5</td>
<td>0.2</td>
<td>0.1</td>
<td>nd</td>
<td>0.3</td>
</tr>
<tr>
<td>1924.0707.6</td>
<td>7</td>
<td>35.21</td>
<td>63.5</td>
<td>34.9</td>
<td>0.4</td>
<td>0.9</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>1924.0707.7</td>
<td>8</td>
<td>34.79</td>
<td>65.3</td>
<td>33.4</td>
<td>0.3</td>
<td>0.6</td>
<td>nd</td>
<td>0.1</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>1924.0707.8</td>
<td>9</td>
<td>34.38</td>
<td>64.5</td>
<td>34.0</td>
<td>0.6</td>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>nd</td>
</tr>
<tr>
<td>1924.0707.9</td>
<td>10</td>
<td>33.54</td>
<td>64.0</td>
<td>34.2</td>
<td>0.5</td>
<td>0.6</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>1924.0707.10</td>
<td>11</td>
<td>33.54</td>
<td>64.7</td>
<td>34.1</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>1924.0707.11</td>
<td></td>
<td>48.2</td>
<td>50.7</td>
<td>0.8</td>
<td>nd</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>1924.0707.12</td>
<td></td>
<td>47.9</td>
<td>51.0</td>
<td>0.5</td>
<td>0.4</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>nd</td>
</tr>
</tbody>
</table>

Notes:
- The percentage silver contents of the coin were calculated from Symonds’s table using the following information: one Troy pound = 5760 grains; one Troy pound = 12 ounces (oz); one ounce = 20 pennyweights (dwt); and one pennyweight = 24 grains.

### Table 2. Numismatic and analytical information for the debased coins of Henry VIII and Edward VI

<table>
<thead>
<tr>
<th>BM registration number</th>
<th>Symonds’s number</th>
<th>Date</th>
<th>Weight (g)</th>
<th>Type</th>
<th>Denom.</th>
<th>Ruler</th>
<th>Silver content</th>
<th>Extent of elongation of the silver-rich $\alpha$ phases</th>
<th>Surface plating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1924.0707.1</td>
<td>1</td>
<td>1529–1541</td>
<td>1.84</td>
<td>Lys</td>
<td>Groat</td>
<td>Henry VIII</td>
<td>Sterling silver</td>
<td>No plating</td>
<td></td>
</tr>
<tr>
<td>1924.0707.2</td>
<td>3</td>
<td>1544–1547</td>
<td>1.48</td>
<td>None</td>
<td>Groat</td>
<td>Henry VIII</td>
<td>Half</td>
<td>Moderate</td>
<td>Thick enrichment with plating layer?</td>
</tr>
<tr>
<td>1924.0707.3</td>
<td>4</td>
<td>1547–1549</td>
<td>1.01</td>
<td>Arrow</td>
<td>Groat</td>
<td>Henry VIII</td>
<td>Third</td>
<td>Severe</td>
<td>Surface enrichment</td>
</tr>
<tr>
<td>1924.0707.4</td>
<td>5</td>
<td>1549</td>
<td>1.03</td>
<td>None/grapple</td>
<td>Groat</td>
<td>Henry VIII/Edward VI</td>
<td>Third</td>
<td>Severe</td>
<td>Surface enrichment</td>
</tr>
<tr>
<td>1924.0707.5</td>
<td>6</td>
<td>1544–1547</td>
<td>1.25</td>
<td>None</td>
<td>Groat</td>
<td>Henry VIII</td>
<td>Third</td>
<td>Little</td>
<td>Thick surface enrichment</td>
</tr>
<tr>
<td>1924.0707.7</td>
<td>7</td>
<td>1544–1547</td>
<td>1.61</td>
<td>Lys</td>
<td>Groat</td>
<td>Henry VIII</td>
<td>Third</td>
<td>Moderate</td>
<td>Thin surface enrichment plus applied plating layer up to 9 µm thick</td>
</tr>
<tr>
<td>1924.0707.8</td>
<td>8</td>
<td>1544–1547</td>
<td>1.50</td>
<td>K/none</td>
<td>Groat</td>
<td>Henry VIII/Edward VI</td>
<td>Third</td>
<td>Severe</td>
<td>Thick surface enrichment</td>
</tr>
<tr>
<td>1924.0707.9</td>
<td>9</td>
<td>1547–1550</td>
<td>1.64</td>
<td>None/E</td>
<td>Groat</td>
<td>Henry VIII/Edward VI</td>
<td>Third</td>
<td>Severe</td>
<td>Applied plating layer up to 5 µm thick</td>
</tr>
<tr>
<td>1924.0707.10</td>
<td>10</td>
<td>1550–1551 nr</td>
<td>Martlet</td>
<td>Groat</td>
<td>Henry VIII/Edward VI</td>
<td>Third</td>
<td>Severe</td>
<td>Amalgam plating layer up to 9 µm thick</td>
<td></td>
</tr>
<tr>
<td>1924.0707.11</td>
<td>11</td>
<td>1544–1547</td>
<td>1.56</td>
<td>Lys</td>
<td>Groat</td>
<td>Henry VIII</td>
<td>Third</td>
<td>Severe</td>
<td>Little surface enrichment</td>
</tr>
<tr>
<td>1924.0707.12</td>
<td>12</td>
<td>1549</td>
<td>4.06</td>
<td>Swan</td>
<td>Shilling</td>
<td>Edward VI</td>
<td>Half</td>
<td>Moderate</td>
<td>Surface enrichment</td>
</tr>
<tr>
<td>1924.0707.13</td>
<td>13</td>
<td>1549</td>
<td>3.29</td>
<td>Y</td>
<td>Shilling</td>
<td>Edward VI</td>
<td>Half</td>
<td>Moderate</td>
<td>Surface enrichment</td>
</tr>
</tbody>
</table>
Figure 2. SEM image of coin 1924,0707.5 showing an as-cast structure with a little elongation and surface enrichment to the right of the image. The brighter areas are silver-rich α phases.

Figure 3. SEM image of coin 1924,0707.12 showing an elongated structure and a surface silver enrichment layer (of c.12 µm) to the right of the image.

Figure 4. SEM image of coin 1924,0707.10 showing an elongated structure and a surface silver enrichment layer that is partly corroded to the right of the image.

Figure 5. SEM image of coin 1924,0707.7 showing an elongated structure and a surface silver enrichment layer to the left of the image that lies above a corroded layer (darker area).

Figure 6. SEM image of coin 1924,0707.4 showing an elongated structure and a surface silver enrichment layer that is being lost to the right of the image.

Figure 7. SEM image of coin 1924,0707.6 showing an elongated structure and an applied silver plating layer on the surface to the right of the image.
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elaboration of the silver-rich α phases in their microstructures (Table 2), indicating that they were struck from a heavily hammered sheet of metal rather than from a cast blank [5]. This explains why all the coins except that composed of sterling silver show almost no porosity and supports the supposition that coin blanks were cut from sheets of hammered metal, which is well attested in documentary and visual sources of the period. Examination of the coins’ microstructure after etching did not provide further useful information.

Surface treatments

The coin with the highest silver content did not show signs of any surface treatment, which would be expected, as the fineness of the coin would be readily accepted by the public. Silver enrichment was clearly present on the surface of the three coins (1924,0707.2, 11 and 12) with approximately 50% silver, again as expected and documented in contemporaneous sources [6; p. 98, 7]. This was probably achieved through blanching the coins in acid before they left the mint. Among the coins with the lowest silver content (approximately one-third silver), two different techniques were used to improve the colour of their surface; as discussed below these techniques may also have been used on some of the coins with a silver content of around 50%. Evidence of surface enrichment was present on coins 1924,0707.3-8 and 10-12. The thicknesses of the surface enrichment layers were difficult to measure due to loss or corrosion but could have been more than 10 μm, Figure 3. Corrosion had occurred in the silver enrichment layer on some coins (1924,0707.10: Figure 4) or under the enrichment layer (1924,0707.7: Figure 5). The silver-enriched layers on coins 1924,0707.3 and 4 were almost lost due to use or burial, Figure 6.

Surface enrichment was used extensively in late Roman coinage [8–10]; before the blank was struck with the die, the surface was attacked with chemicals to oxidize the copper, which could then be removed with dilute acid to leave a silver-rich layer [3, 9, 11, 12]. A sixteenth-century source describes the blanching process for gold thus: “[the blanks] are thrown into a common blanching liquor made with powdered tartar, salt and water, or urine. In this way the gold is cleaned and brightened and then the pieces are washed well with clear water. When dried, they are sent to the dies and thus coined they are finished so that they have only to be spent” [7; p. 360]. It goes on to indicate a variation when blanching silver: “some rock alum is put in the blanching liquor in addition to tartar and salt because they whiten better” [7; p. 361]. The compact silver-rich layers present at the surface of most of the coins confirm that they were formed before striking [13].

The other method used in the production of the lower silver content coins was the application of silver plating to their surface, a technique that is not found in the written sources. This applied layer was clearly present on coins 1924,0707.6, 8 and 9, Figures 7–9. Analyses by SEM-EDX showed the presence of mercury on 1924,0707.9, which indicates the use of silver amalgam for the production of the silver plating on this particular coin, identified as mint-issued rather than a contemporaneous forgery. Amalgam plating was also reported on one of the unprovenanced coins of Henry VIII analysed by Bayley and White [3].
amalgam plating was introduced for the production of debased late Roman coins in AD 260, when the silver content dropped drastically (to less than 5%) and this composition remained in use until the end of the third century AD [10]. Amalgam plating might also have been used on the other two coins presenting evidence of applied plating (1924,0707.6 and 8), but an analytical technique that is capable of detecting trace amounts of elements such as laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) – might be required to determine if mercury remains at extremely low levels. Experimental studies have demonstrated that a layer with mercury present at a level of less than 0.5% can be prepared with a thickness (c.2 µm) comparable to that observed in coin plating layers [10]. These experimental results indicate that the coins could have very low mercury concentrations on their surface immediately after their production. The wear and corrosion they suffered subsequently would have resulted in the reduction of the mercury contents to levels that might not be detectable, even with sensitive analytical techniques such as LA-ICP-MS or electron probe microanalysis [14]. Other silver plating techniques used for coin production, including silver foil, molten silver and silver chloride [15], could have been employed for the coins of Henry VIII but there was no evidence of these methods within the group of coins analysed for this study.

An interesting discovery from this study was that both surface treatment techniques mentioned above might have been used concurrently. For coin 1924,0707.2 there was evidence not only of surface enrichment, but also a thick patch of silver in a recessed area on the surface (Figure 10), which suggests that a plating layer was applied to improve the appearance of the silver. As this coin had a silver concentration of c.50%, surface enrichment alone should have been sufficient to provide an improved silver appearance. The application of the plating layer might indicate a period of experimentation by the mint workers. The surface and metallographic examination of coins from AD 240 to 253 provided evidence that during this transitional period of the Roman coinage both techniques (surface enrichment and applied silver layers) were used on some of the coins to test a new technology for the production of the further debased coinage [10].

While the use of plating techniques is today more closely associated with the counterfeiter’s art than a legitimate practice used in a mint, the evidence of Roman coins shows that plating was a process sanctioned in times of great and rapid debasement. As such there is no reason to consider the presence of plating as evidence for a form of nefarious activity in the mint. Instead it reveals the pressure that the mint workers were under to find ways to create coins that both heeded the new mint standards and remained acceptable to the public. It also shows that mint workers possessed the knowledge and skills to apply sophisticated and delicate plating technology, the presence of which has only now been revealed through the use of modern analytical techniques and equipment.

Conclusions
All the Henry VIII coins examined in this study were found to be silver-copper alloys and appear to fall into three groups: one coin is of sterling silver, three contain c.50% silver and the remaining eight contain approximately one-third silver. The results of this study are generally consistent with Symonds’s assayed data and with what is known of the debasement sequence in that period. However, the scientific analyses presented here also provide accurate quantification of the major and minor elements of the alloys used for the coins and reveal the techniques used in their manufacture and surface treatment.

Most of the coins showed severely elongated silver-rich α phases in their microstructures, indicating that they were struck from a heavily hammered sheet of metal rather than from a cast blank. The silvery appearance of the coins containing c.50% silver was achieved by deliberate removal of copper from the surface metal prior to striking, although some may also have been plated. The coins that contained approximately one-third silver showed evidence of surface silver enrichment from blanching and in some cases there seem to be distinct traces of silver plating, with one confirmed instance of silver amalgam plating.

This use of silver amalgam plating suggests that undocumented plating techniques were used in the mints concurrently with other (documented) techniques, such as blanching, to enrich the surface layer. Given the difficulty of identifying the traces of mercury characteristic of amalgam plating, especially on coins where the surface layer has been subject to considerable wear, the question arises of whether amalgam plating was more common than previously thought. Not everything that went on in the mint was documented and new analyses of the type presented here are important in uncovering the differences between an ideal mint situation and the reality of delivering a challenging debasement under royal orders.

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References


Scientific examination of the Roman ring-pommel sword said to be from Pevensey, East Sussex

Janet Lang and Ralph Jackson

**SUMMARY** A ring-pommel sword said to have come from Pevensey was repaired before being acquired by the British Museum. X-radiography showed three decorative composite bands running down the blade. Two tiny fragments of the repair metal and a wedge-shaped, half-width section removed from the blade were obtained to enable the study of the metallographic structure, composition and hardness. The repair metal appeared to be pure iron, used to weld the ring, tang and blade together after excavation. Overall, the metal in the blade section contained little slag. The pattern bands consisted of alternating strips of mild steel and phosphoric iron. The carbon content varied between negligible and 0.6%. The cutting edge appears to have been encased in a layer of ferritic iron with a low carbon content (0.1%). The reason for this is not clear; some early swords had softer outer layers with a hard core that could be exposed by grinding away the surfaces at the edge, but it is more probably the result of decarburization.

**The sword and its origins**

In 2004 the British Museum purchased a Roman iron sword and copper-alloy chape said to have been found at Pevensey during the Second World War, Figure 1a [1, 2]. Complete identifiable Roman swords are not common in Britain and this was a notable addition to the national collections. The sword appeared in reasonable condition, but some restoration was suspected. Accordingly, conservation and scientific investigation were scheduled and took place during 2005–2006. X-radiography and cleaning revealed ancient manufacturing techniques as well as disclosing post-discovery repairs and restoration, Figures 1b and 1c [3, 4]. Scientific examination, including sampling of the blade and metallographic analysis, followed. Since 2007 the sword has been displayed in the Weston Gallery of Roman Britain (gallery 49) alongside other swords from Roman Britain.

The sword (British Museum 2004,0301.1) is an example of the type known as a ring-pommel sword or ‘Ringknaufschwert’, on account of the distinctively shaped ring at the end of the grip, Figure 2 [5; pp. 87–88, type II, 6; pp. 149–150 and 177–180, 7; pp. 33 and 186–187]. It is made of iron, 69.3 cm in overall length with a relatively short and broad parallel-sided, double-edged blade that ends in a short tapered tip. The blade is Miks’ ‘Hamfelde’ type [6; pp. 69–70, taf. 10]. The blade edges are quite extensively chipped but they retain the original edge in many places. Characteristically, the sword has an all-iron hilt assembly that terminates in the ring-pommel, which is a thick ellipse with a near-circular eye. X-radiography revealed a scarf weld at one end of the ellipse at the junction with the hilt. At its blade end the hilt incorporates the usual – and equally distinctive – bar-shaped hilt guard, separately forged and with neatly bevelled edges. The scabbard and hilt fittings, of leather, wood or bone, have perished.

The copper-alloy chape (British Museum 2004,0301.2) – the decorated protector for the end of a sword scabbard – is a large circular box-chape with tinning and incised decoration on both faces, Figure 2 [6; pp. 345–350]. The front face has a triple-ring incised moulding at the perimeter and near the centre, where the perforated centre point is at the apex of a low dome. The back face has a lightly incised ring-moulding around the perimeter and a double ring-moulding near the centre, which is flat with a perforated centre point. The wall apertures that accommodated the scabbard end comprised a
broader upper slot and a narrower lower slot. The upper slot is a little distorted and split with a fissure running down the front face almost to the centre and two shorter fissures down the back face. An elliptical portion of the back face adjacent to the lower slot has broken away in an area of slight crushing. The dimensions and masses of the sword and chape are listed in the technical appendix.

Confirmation of the provenance of the find has proved elusive. According to a handwritten letter — the only documentation that accompanied the objects — the sword and chape had been in the hands of at least five successive owners before being purchased by the antiquities dealer from whom the Museum acquired them. The undated letter was signed by J. Corrigan and addressed to Mr Blades, probably a potential purchaser of the sword and chape. The writer, who refers to a previous conversation with the addressee, explains that the objects were bought from his (or her) brother who had inherited them from his (or her) father, a collector. Mr Corrigan senior had purchased the objects around 1962 from Mr Leon Cooper, described as “a well-known West Yorkshire antiques dealer” who, in turn, had bought the sword “with much else, from a Dr Clay, of Earls Leeton (sic) nr Dewsbury, West Yorkshire”. The writer continues “I remember there was a letter and newspaper cutting regarding its discovery in 1940 at Pevensey in Sussex, the sword was found in the village, just outside the castle, during some drainage works. Together with the sword and its chape were also some Roman silver coins of Commodus – 177–192 AD. What happened to the coins and relative documentation – I do not know. My father was not too careful with things.”

The account has a genuine sound to it but even so might include errors of memory. It seems unlikely to have been a complete fabrication but that possibility cannot be excluded. Enquiries in 2004, and subsequently, made of museum, university and planning department colleagues in the Sussex region, together with those involved in archaeological fieldwork in the Pevensey area [8], as well as a search of the local newspaper, the Sussex Agricultural Express, for the year 1940, provided no corroboration of the stated provenance or the circumstances
of the find. In addition it has not been possible to substantiate the subsequent history of the objects as described.

While confirmation of at least some of the account would certainly have been useful, its lack does not necessarily make the account untenable. Indeed, the situation prevailing at Pevensey in 1940 would make such a find perfectly feasible. One year into the Second World War there was intense activity at and around Pevensey Castle, as the region was regarded as especially vulnerable to enemy attack following the invasion scare caused by the evacuation of Dunkirk in May and June 1940. Pevensey was one of the four subsectors of ‘C sub-area’ of the Sussex coast defended by the 219 Infantry Brigade of 45 Division in the critical period between August and October 1940, when invasion was a real danger and Pevensey Castle was the headquarters of the 11 Battalion of the East Surrey Regiment [9; p. 3]. The immediate response was to secure the existing surviving stretches of the perimeter defences of the Roman stone fort and Norman castle by adding pillboxes, machine gun emplacements, baffle walls and anti-tank blocks. Such rapid and intense construction may well have precipitated the claimed “drainage works” and under those circumstances — the fear of an imminent invasion — there would have been considerable scope for a modest archaeological discovery to receive little attention.

If the stated circumstances of the discovery are accurate, the objects — especially the iron sword — were likely to have been in a soil-encrusted and corroded state. It is also possible that the sword was bent and damaged, either in ancient times or upon discovery, as the conservation examination and treatment revealed signs of the blade having been straightened. At some stage repairs were also made to the hilt: areas were abraded, the blade, grip and pommel were joined by welding and an acrylic-based resin containing iron was applied to areas on the hilt and blade, Figure 1c [4]. Those repairs are regrettable because they obscured the original constructional details of the hilt assembly. Additionally, the blade appears to have been heated, which has confused the evidence for ancient heat treatment during manufacture.

Although details of the find and context are irretrievable, the survival of a complete sword together with a chape might be taken to imply that the sword had been deposited intact in a scabbard, which might, in turn, suggest that the sword and (now missing) coins were part of a soldier’s burial; many ring-pommel swords have been found in burials. Such an interpretation, however, encounters some difficulties, as the form of the chape does not match that normally associated with ring-pommel swords. Furthermore, the dating of sword and chape is not identical.

Ring-pommel swords, with their novel pommel and all-iron hilt assembly, were a radically different Roman sword type. They originated quite early in the second century AD, almost certainly imitating swords of the Sarmatian tribes of the western steppes, who were in contact with Rome both as neighbours and, in the later second century, as enemies in the Marcomannic Wars. Consequently, the swords are concentrated in Romanized Germany and in free Germany (beyond the frontier), where they have frequently been found in burials. However, they have a wider, sparser distribution throughout Europe with the exception of the Mediterranean littoral [10; pp. 122–125 and fig. 167]. Roman Britain was at the western periphery of the distribution and although broken blades are impossible to assign with confidence, identifiable fragments include a handle from the town of Silchester (Calleva Atrebatum). This uncatalogued fragment in Reading Museum measures 121 mm in length, 67 mm in width, has a single rivet hole in the hilt and is comparable to an example from the massive ancient weapon deposit at Vimose in Denmark [6; taf. 183, B308,9].

Ring-pommel swords appear to have become particularly popular in the second half of the second century and may have remained current into the early decades of the third century [5, 6; pp. 180–187, 7; p. 213, 11; pp. 131–133]. Of about 60 fairly complete examples catalogued by Miks, only three have a securely associated chape and in each instance it is of peltate form [5; A280, A346 and A485]. The ‘Pevensey’ chape is a circular box-chape and if it was truly associated with the ring-pommel sword would be the first occurrence of that combination. Miks knew of no British parallel but subsequently a similar box-chape was recorded as a casual find from Flag Fen, near Peterborough, Cambridgeshire.1

Like ring-pommel swords, however, the majority come from Romanized and free Germany, and the closest parallel is an example from a third-century child’s grave recently excavated at Jadowniki Mokre, southern Poland [12]. Ring-pommel swords date principally to the second century while circular box-chapes date mainly to the third century [6; pp. 349–350], but there is the possibility that in Britain in the late second century, a replacement scabbard for a ring-pommel sword was fitted with a new type of chape. Alternatively, the sword and chape may not belong together or may not even have been found together, and Miks has correctly characterized the provenance of the ‘Pevensey’ sword and chape as “Fundort unsicher” (findspot uncertain) [6; pp. 183–184, 350, 587, A191, taf. 44, taf. 181 and taf. 253].

If the sword and chape were deposited at Pevensey around the late second or early third century AD (the best ‘fit’ for the combination of sword, chape and coins), that would have been about a century before the establishment of the ‘Saxon shore’ fort that, according to the latest dating evidence based on coins, pottery and dendrochronology, was constructed shortly before AD 300, probably during the usurpation of Allectus in AD 293–296 [13; pp. 60–62, 94–98 and 123–124]. But Pevensey may already have seen military activity in the second and early third century related to the operations of the Classis Britannica, the British fleet, as its stamped tiles have been found at Pevensey and other coastal sites in south east England. In addition there is archaeological evidence of a fairly extensive occupation of the site from the first to the third century AD, but whether military or not is presently unclear [13; p. 123]. Although it is conceivable, therefore, that the deposition of the sword and chape occurred towards the end of that period at Pevensey, the question of provenance should remain open.

Examination of the sword

After the initial examination to assist conservation work, a further metallographic study was undertaken to elucidate the construction and composition of the sword, as very few ring-pommel swords have been technically examined. X-radiography gave no further indications of the function of the bright metal (between 160 and 240 mm from the tip
of the blade), but showed decorative pattern-welded stripes running down the blade (Figure 1b), as well as the scarf weld mentioned above [3]. It was decided to remove a small sample for metallographic examination. After careful consultation, to ensure that the sample was taken from the optimum position to provide information while maintaining the integrity of the object, a wedge-shaped section was removed in the conservation studio. Small fragments were removed from the areas of white metal (possible welds) to determine, if possible, their nature.

**Microscopic examination**

The wedge-shaped specimen was cut from one of the cutting edges to the mid-width, 175 mm from the shoulders of the blade. It was 21.5 mm in length and had a maximum width of 3 mm at the cutting edge. It was mounted in cold-setting resin together with the two fragments of white coloured metal, one from the tang and the other from the ring. The mounted samples were ground on carborundum paper lubricated with water and then polished with 6 µm and 1 µm diamond pastes using a proprietary polishing fluid.

After polishing, the sections were examined by optical microscopy. The blade sample contained relatively few small inclusions: these were aligned mainly parallel to the surface of the blade, except in the area of the just-visible pattern bands, where the inclusions were generally oriented in a more transverse direction (i.e. from one surface of the blade to the other). The two small samples of white metal were featureless with a few minute inclusions.

To reveal the metallographic structure, the sections were then etched with 2% nital (nitric acid in methanol). This showed that the small white metallic samples from the joins were almost completely ferritic (i.e. pure iron) and contained many very small globular inclusions. Taken with the data from energy dispersive X-ray analysis in the scanning electron microscope (SEM-EDX) reported below, these results strongly suggest that the fragments are from welds, probably carried out soon after excavation.

The etched blade section itself showed a more complex structure, confirming the X-radiographic evidence that it had been constructed from several components, Figure 3. It was made with a decorative central section joined to a wide edge section that tapered to the cutting edge, and appeared to consist of three layers.

**Central section**

The central section of the blade (only half of which is visible in the mounted half-blade cross-section: Figure 3) appears to consists of a middle strip of steel (c.0.3% carbon) comprising rather coarse and slightly acicular ferrite and pearlite, flanked on either side by a composite of four or five alternating strips of phosphoric iron – identified by SEM-EDX – and narrower strips of steel (pearlite and ferrite) running from surface to surface, Figure 4a. Very small globular inclusions can be seen in both the phosphoric iron and the pearlite-ferrite (mild steel) strips. These have bent during working and at one surface (the lower side in Figure 3) the wider phosphoric strips seem to have almost ‘smeared’ over, so that the intermediate strips of mild steel were probably not visible on that surface, although they might have been slightly more discernible on the opposite surface. After repolishing, the fresh section revealed that the steel cross-bands did not extend as far as the surfaces and they were even less likely, therefore, to have been visible at the surfaces at this point. This is surprising and it may perhaps simply be a localized affect. It is possible that the phosphoric iron bands, which were thicker than the mild steel strips, might have deformed more readily and folded over those of thinner mild steel, enclosing them completely at the outside surfaces. Preferential corrosion of the steel bands, with respect to the adjacent phosphoric iron bands, may also have taken place. If the alternating strips were not visible on the surface, it is difficult to understand why they were introduced.
**Edge section**

In the metallographic sample, the width of the edge is 17.5 mm, measured from the transverse strips to the cutting edge, but the X-radiographs show that the distance between the composite bands and the edge is not constant throughout the length of the blade. The edge section consists of a tapering steel core with pearlite and ferrite phases and a thin ferritic outer layer towards the cutting edge, Figures 3 and 5. Adjacent to the transverse strips, the steel surface is depressed and somewhat rough, suggesting that ‘blood channels’ or grooves had been ground into the surface.

The carbon content of the core is generally c.0.3%, although there is an irregular band with a higher carbon content (c.0.6%) but this does not appear to have been a separate layer originally. The carbon content of the middle layer increases slightly near the decorative cross-bands. The grain size is larger along the axis and then decreases slightly towards the surface. The steel core tapers to a virtually negligible thickness at the cutting edge.

The ferritic surface layers converge towards the cutting edge, their thickness changing very little, only tapering slightly at the cutting edge itself, Figure 6. The layers appear to be approximately 0.4–0.6 mm thick, but the original thickness may have been reduced by corrosion. The surface metal at the cutting edge is softer (97 HV 0.1) than the core (159 HV 0.1), Figure 6. There is no evidence, such as slag or oxide particles at the interface, to suggest that the layers were fire-welded together when the blade was constructed. The interface between the layers is very distinct (Figure 5), and the gradual change in carbon content that occurs when a surface has been decarburized is not observed [14; p. 531]. Many of the grain boundaries in the ferrite seem to have been initiated at features on the interface with the core. There are no signs of a final cold-working process in the surface layers, but the inclusions are elongated, indicating prior working during forging had taken place, Figure 5. The ferrite grains are quite large and contain a small amount of carbon (c.0.1%) in the form of small slivers of iron carbide and smaller precipitates of iron carbides or carbo-nitrides.

After optical examination, the sample was coated with carbon under a vacuum to provide a conducting surface to prevent charging during imaging in the SEM. The compositions of the metal and the non-metallic inclusions (mainly slag) were determined using EDX analysis and the results are given in Table 1.

The results from SEM-EDX analysis confirm that the light etching strips contain c.1% phosphorus (Figure 4, right), and that the inclusions within the strips (both two-phased larger inclusions and small globules) are mainly slag-containing, with iron oxide, silicon, phosphorus and manganese in some cases. Vanadium and nickel were not found (within the detection limits of the system).

The results also show that the metal in the surface layers and the core of the edge section contained only iron and carbon (not quantified); again no trace elements were present within the detectable limits of the system. There were few inclusions and all those analysed contained variable amounts of aluminium, silicon, iron and manganese, classed as slag, a waste product of the extraction process. Manganese was present in the inclusions of all three layers of the edge section but not in the phosphoric iron, while phosphorus occurred in the phosphoric iron cross-strips and the inclusions within them, but not in the other ferrous components, suggesting two different ore sources for the iron and steel.

The two samples of ferrite from the welds were almost pure iron with traces of silicon, manganese and chromium, the last of which was not found elsewhere in the analyses. This is typical of some weld metals and strongly suggests that the sword had been repaired by fusion-welding the tang, sword and ring together at some time after their discovery.

**Discussion and conclusions**

The sword has been repaired and straightened, evidently after discovery, and it is not certain how much of the structure has been changed as a result. It is probable that the blade and tang were originally a single piece of metal, although they are now joined by modern welding. The ring has a scarf weld that is
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Notes
The results are quoted as oxide, normalized to 100%. The precision is taken to be 2 sigma which is 1.5% or less for iron and less than 0.5% for other elements. The accuracy is ± 1–2%. Abbreviations used are as follows: nd = below detection limits (less than 0.07% for all elements except iron); A = area analysis (not precisely measured); B (with number) = transverse bands (B1 is nearest to the cutting edge); C = core; HC = higher carbon (0.6%); I = interface between core and surface layer; M = approximately midway between the long axis of the sword and the cutting edge; P = phosphoric iron; S = surface layer; T = near cutting edge; X = similar inclusions; and Y = similar inclusions.
probably part of the original construction, but it has also been recently welded to the tang. As a result, it is not easy to see how the ring itself was made and originally attached or, indeed, if it was an extension of the tang. The lack of documentation of the circumstances of its discovery does not help to explain whether the sword was lost or deliberately interred. At the same time, there is no clear evidence to suggest whether or not it was deliberately bent and broken before it was abandoned.

As the X-radiographs show, the blade was constructed with a central panel decorated with three composite bands running down the blade from hilt to tip [3]; this arrangement is similar to a ring-pommel sword from grave 106 in a cemetery at Krupice, Poland, examined by Biborski et al. [15]. In both examples, blade cross-sections show that the bands consist of alternating strips of steel and phosphoric iron. These metals have differing etching characteristics. The steel strips, when treated with an acid such as vinegar or after exposure to the atmosphere, would have darkened while the phosphoric iron strips retained a bright, shiny appearance, resulting in a striped pattern on the surface of the blade. The broader pearlite and ferrite areas between the bands would also appear darker after etching. Type of simple pattern-welding was noted on a Roman dagger from Kingsholm [16], while Gilmour has also described its use in the Roman period and later [17, 18].

The presence of a ferritic surface on the edge section is somewhat surprising; although it has a bright and shiny appearance, it is not very hard and would have scratched easily, Figure 6. The layer might have been deliberately introduced by applying an iron layer around the edge. An example of this type is found on a Roman sword from Augst (inv. no. 1961.4401), where a harder, carbon-rich core was enclosed by softer, low-carbon surface layers [19]. The harder metal protruded to make a hard cutting edge. However, in the mounted sample, the harder core of the ‘Pevensey’ sword is exposed towards the middle but does not actually protrude to make the cutting edge, although this section may be atypical of the whole blade. Another more likely possibility is that the surface could have resulted from decarburization under specific conditions. According to Janusz Stepiński, who has examined a number of swords from cremation graves in Poland, holding a steel blade between 723 and 912°C can result in a surface layer with an abrupt transition from ferritic columnar grains to a higher carbon core [20]. The result of this heating sequence is demonstrated by Houdremont [21; p. 128] and observed in a section from the sword from grave 134 in the Krupic cremation cemetery [15; figs 8 and 9]. Unfortunately, as the details of the present find are lacking, there is no means of knowing if the sword was part of a cremation burial that might have produced the effect, but it is clear that it was heated post-exavcation. It is impossible, therefore, to be certain if the layered structure at the edge was deliberate or the result of heating and holding between 723 and 912°C before or after excavation. The presence of the carbide precipitates may be the result of a heat treatment process, either after quenching (quench ageing) or during burial, as they are often observed on excavated iron objects [22; p. 54]. A heat treatment during restoration might also be responsible.

In conclusion, the examination has shown both that the sword was repaired after discovery, by welding and probably straightening, and that the blade has a complex structure.

The metal for the central panel and the edge originated from different sources and is of good quality, particularly the steel, with relatively few inclusions. Phosphoric iron was used to make the light etching iron in the decorative strips in the centre panel. Manganese was present in the ores used to make the edges. The decorative cross-strips consist of alternating bands of steel and phosphoric iron. The edges are unusual as they consist of soft outer layers of ferrite and a harder steel core. This may be the result of decarburization or of forge-welding an even thickness of wrought iron onto the steel surface, a skilled operation, with no flaws visible in the section. If wrought iron was used deliberately, it is surprising that the edge was not ground away to expose the harder core to improve the cutting edge. It seems more likely that it is a result of decarburization, although when this occurred cannot now be determined.

**Technical appendix**

**Sword**

- Total length: 693 mm
- Length of blade (to underside of hilt guard): 505 mm
- Length of hilt and pommel (from underside of hilt guard): 188 mm
- Length of hilt (upper side of hilt guard to underside of pommel): 110 mm
- Maximum width of pommel: 70 mm
- Width of blade (45 mm below base of hilt guard): 54 mm
- Width of blade (just below mid-point): 52 mm
- Width of blade (immediately above taper to tip): 47 mm
- Width of hilt guard: 72 mm
- Width of hilt: 18 mm
- Thickness of blade: 6 mm
- Maximum thickness of hilt guard: 20 mm
- Thickness of hilt: c.5 mm
- Maximum thickness of pommel: c.20 mm
- Mass: 750.7 g

**Chape**

- Diameter: 73.7 mm
- Thickness: 9.5 mm
- Dimensions of upper (wider) aperture: 40 × 7.6 mm
- Dimensions of lower (smaller) aperture: 17 × 3 mm
- Mass: 91.3 g

**Hardness**

- Weld material on repair: 140 and 134
- Cutting edge: 103
- Surface (ferritic) layer near cutting edge: 92 and 101
- Middle layer (pearlite and ferrite) near cutting edge: 159
- Surface layers (ferritic): 109, 114 and 93
- Steel with up to 0.6% carbon (middle of blade): 194 and 206
- Decorative strips with light etching: 177, 187, 175 and 206
- Decorative strips with dark etching: 172, 165 and 131
- Core (centre of blade): 145
Acknowledgements
The authors would like to thank Janet Ambers for X-radiography, Tony Simpson for imaging, Simon Dove for conservation, Fleur Shearman for sampling and advice on conservation issues and Dr Quanyu Wang for general discussions. The generous advice and information supplied by Dr Janusz Stępinski and Dr Michał Grygiel is very gratefully acknowledged.

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References

Note

Scientific examination of the Roman ring-pommel sword said to be from Pevensey, East Sussex | 95
Conservation treatment and technical observations on two objects from the Waddesdon Bequest with life castings

Maickel van Bellegem, Dora Thornton, Paul Buck and Susan La Niece

SUMMARY

The huntsman automaton (British Museum WB.134) by Wolf Christoff Ritter and the silver bell (WB.95), known as the 'Cellini bell' but now attributed to Wenzel Jamnitzer, both from Nuremberg (Germany) and with life-cast silver elements, have undergone conservation treatment and examination. The life-casting technique used real plants and animals as models, and received high acclaim during the sixteenth and seventeenth centuries. These two objects from the Waddesdon Bequest are placed in their historical context and their collection history is traced. Technical observations and the condition of the objects are described and illustrated.

The life-cast silver elements on the automaton have sustained losses and old solder repairs obscure much of the surface detail. No remains of a naturalistic paint or varnish are now detectable; if present originally they were probably lost in the process of the solder repairs, influencing the decision to remove tarnish to expose the whitened/blanched silver surface. The mechanical components driving the automaton were removed and examined to assess the potential for allowing it to operate. It was concluded that to enable this, two teeth on the intermediate winding wheel would need to be replaced. This course of action is fraught with danger because of the high temperatures required and the risk of breakage of what appears to be the original mainspring, so this was not pursued.

In 2011 tarnish was noted on the bell that altered the subtle sheen of the silver. This contribution offers a record of observations made on the variations in the finish of the silver surface: a strongly etched surface and a matt whitened/blanched surface contrast with the reflective surfaces of the worn and burnished areas of the high relief. The technical features of the bell and the results of X-ray fluorescence analyses are discussed and placed in context along with a discussion of the technique for etching silver.

Introduction

The 'Cellini bell' (WB.95: Figure 1) and automaton in the form of a huntsman (WB.134: Figure 2) are both objects from the collection known as the Waddesdon Bequest, which was left to the British Museum by Baron Ferdinand de Rothschild MP (1839–1898) at his death. Named after Waddesdon Manor in Buckinghamshire, where the collection was housed in Baron Ferdinand's lifetime, the bequest is unique within the British Museum. Baron Ferdinand, who had been born into the famous Jewish banking family in Frankfurt, made England his home from 1860, marrying his English cousin and becoming a British citizen. He served as a Justice of the Peace, High Sherriff of Buckinghamshire and as a Liberal MP in the 1880s, as well as being a major donor to charities and a leading member of the Jewish community in London. During his lifetime he augmented the superb cabinet collection left to him in 1874 by his father, Baron Anselm of Frankfurt and Vienna (1803–1874) and displayed it in the New Smoking Room at Waddesdon Manor from 1896.

Both objects considered here have long been admired as masterpieces and rare survivals of goldsmiths’ work. They were made in Nuremberg within about 60 years of each other by leading master goldsmiths. The bell is unmarked but can be firmly attributed to Wenzel Jamnitzer (master 1534, died 1585) on stylistic and technical grounds and dated to c.1560. The automaton is marked for Wolf Christoph Ritter (master 1617, died 1634) and can be dated to c.1617–1620. Both demonstrate the artistic ambition and accomplishment of their makers and the technique of life-casting insects and plants.
Both objects are encrusted with life-cast animals and foliage as virtuoso examples of the Renaissance fashion for taking forms – as well as artistic inspiration – directly from nature [1, 2]. Such pieces were ideally suited to the Kunstkammer of a Renaissance ruler, the kind of cabinet collection of small-scale treasures formed by German princes to demonstrate power and discernment [3].

The bell and automaton were included in a study day focusing on life-cast silver held at the British Museum in conjunction with the conference on *The Renaissance Workshop* in 2012. This contribution presents a historical context together with observations on technical features made during conservation of these objects. As part of the Waddesdon Bequest they were put on permanent display in June 2015 in a new gallery dedicated to the Bequest, in room 2a (formerly known as the Middle Room), the British Museum’s original reading room.

**Automaton WB.134**

This automaton in the form of a huntsman was acquired by Baron Anselm before 1866 when it was first catalogued (no. 198) by Schestag [4, 5; pp. 305–308]. Marked twice for Wolf Christoph Ritter of Nuremberg and made around 1617–1620, it is a rare survival from the heavy drinking culture of the period, complete with its original (no longer functional) mechanism [6; pp. 260–268]. The silver figure of a huntsman wearing contemporary dress and a single earring in line with male fashion advances into the forest with a boar spear in his hands and a dog on a heavy chain at his heel. His head can be removed so that his hollow body forms a stirrup cup. The huntsman stands on a silver mound that has an applied ornament of separately cast lizards, insects, leaves and plant sprigs, suggesting the forest floor on which the hunt takes place, Figure 3.

Hidden under the dome of the mound is a steel clockwork mechanism that propels the huntsman forward on three wheels. According to the dining custom of the time, the person in front of whom the automaton stopped was expected to drink all the wine from the figure. Automata fascinated contemporary rulers and were quintessential Kunstkammer objects [7; p. 201]. Augsburg was very much the centre for these clockwork-propelled drinking vessels made for Baroque
courts in central and northern Europe around 1600, which makes this Nuremberg-made huntsman automaton all the more significant.

**Condition and technical observations**

Both the silver and silver-gilt surfaces had developed tarnish, in particular on the silver-gilt surface, where the tarnish showed an irregular liquid-like pattern. The life-cast silver detail may originally have been cold-painted or varnished as there is evidence of this Renaissance fashion for realistically painted surfaces on other objects and from historical manuscripts [1, 2, 8, 9]. The automaton was examined under ultraviolet (UV) light, which gave no indication of traces of paint being present; the yellow luminescence observed in crevices on the huntsman figure is likely to be associated with waxes or grease.

Excess solder on the life-cast elements on the base obscured some of the surface detail (Figure 3), and the roughness of execution suggests that these are repairs. Such repairs, which would require a high temperature, would have removed any original paint had it been present.

Previous treatments recorded in the Museum’s conservation dossiers date from 1971, 1985, 1994 and 1998. These typically involved the removal of dust and tarnish from the surface using Goddards® Hotel Silver Dip (acidified thiourea) and/or Duraglit® wadding metal polish in combination with steam cleaning.

**The mechanism**

In general, the trains of wheels that drive automata are very similar to a clock striking train, comprising a great wheel, hoop wheel, warning wheel and fly. A description and exploded view of the mechanism in the huntsman automaton can be found in Tait’s catalogue [6; p. 263].

The winding square is located on the underside of the movement and has an intermediate winding wheel mounted on the top plate; this meshes with a winding wheel. As this is offset from the centre of the spring there is presumably an unseen pinion underneath that engages with a pinion on the barrel arbor. There must also be a ratchet wheel and pawl connected to the intermediate winding wheel, which is connected to the great wheel.

A single slotted count wheel mounted on the underside of the mechanism governs the duration of the run. This is driven by a pinion mounted on an extended arbor on the underside of the great wheel. When the sprung detent on the underside finds a slot in the count wheel, it allows the detent in the movement to drop into the hoop wheel and the locking piece to come up against the tab on the locking wheel, thus arresting the train. The great wheel has two pinions at its lower end: the upper engages with a wheel with bevelled teeth on its lower side, which in turn engage with a pinion integral with the driving axle.

The whole movement is made of iron but appears to be very well preserved with the exception of an area of rust on the warning wheel. Access to the movement is through a four-pinned fixing on the underside and cleaning the movement presents no problems.

There are two damaged teeth on the intermediate winding wheel: one is missing over half of its body while the other is bent over and fractured. Winding the mechanism will endanger these teeth. Wheel teeth can be repaired by filing out the damaged teeth and hard soldering in a dovetailed section of new metal that is then filed to the profile of the existing teeth. Undertaking such a repair would potentially allow the movement to run, but this course of action is fraught with danger because of the high temperatures involved and, although facilities are available at the British Museum, this type of intervention would not usually be carried out on a similar mechanism from a Museum clock. Another factor to take into account when considering running this mechanism is the age of the mainspring and the high risk of breakage of what appears to be an original component. It was decided, therefore, not to attempt to run the mechanism and only to clean it in its current state.

**Treatment**

After discussion it was decided to remove as much as possible of the tarnish on both the silver-gilt elements and life-cast silver, including as much of the tarnish in the recessed areas of the decorative/surface detail as was considered feasible and safe. The aim was to expose the matt white silver-enriched surface. The screws on the underside were removed to release the base-plate, movement mechanism and, finally, the screws securing the hunter and dog. The spear was slid out of the hands of the hunter to allow the chain to be disengaged. The movement, the assessment of which is described above, was cleaned using pegwood (sticks of hard wood) and Bergeon® 6033 Rodico (a cleaning putty in the form of a stick, which picks up dust and absorbs oil).

The interior of the hunter is blocked off at the limbs to create the container for the liquid (c.180 mL), although small openings into the hollow spaces are present in the feet and one hand. The torso, head, spear and base with life-cast elements were cleaned by applying Hotel Silver Dip using a squirrel-hair brush, followed by rinsing with tap water and immersion in running tap water for a minimum of one hour. The interior of the hunter figure was rinsed with industrial methylated spirit (IMS) using a bottle with a long nozzle to apply the IMS within the leg and arm cavities. The surfaces were then steam-cleaned and dried using tissue paper and a hot-air gun. The surface of the hunting horn, which it has been suggested is a later addition/replacement, appeared to re-tarnish during the rinsing process. Because the horn has a polished rather than whitened surface, this tarnish was removed using cotton wool with white spirits and Silvo® silver and chrome wadding polish (comprising white spirits, Neuberg chalk and china clay). The surfaces were swabbed repeatedly with white spirits and finally IMS on cotton wool to remove any residues. After treatment, the appearance of the silver surface on the life-cast elements on the base was duller and darker grey than expected. This may be due to the excess solder present from the repairs, which would have been of an alloy with a lower silver content. After the cleaning was complete all the elements were reassembled.

**‘Cellini bell’ WB.95**

The ‘Cellini bell’, which Baron Ferdinand acquired before 1883, represents his personal taste for the curious and historical in collecting; for a full description see [5; pp. 310–317]. The bell had belonged to the great English collector Horace Walpole (1717–1797), whom Baron Ferdinand greatly
admired, which would have increased its value and interest. Walpole attributed the bell to Benvenuto Cellini, the famous Italian Renaissance goldsmith [6; p. 99, 10; p. 487].

Collectors were well aware of the interest in life casting shown by goldsmiths and sculptors of the Italian Renaissance, from Cennino Cennini’s *Il libro dell’arte* of the fourteenth century to Giorgio Vasari’s treatise, published in 1550 [11; pp. 140–141, 12; p. 166], and the bell demonstrates this technique perfectly. Around the body is a repeating pattern of wriggling paired lizards beneath lion masks that hold heavy garlands of foliage and flowers. Between the heads of the pairs of lizards, as they turn towards each other, is an insect or grasshopper. On the domed top of the bell are cockle shells and ‘firebugs’. There are also snails and minute toads, while the opening of the bell is fringed with a thick wreath of leaves and buds. For all the profusion and depth of the high relief, the decoration is carefully conceived and laid out so as to be rich rather than confusing. The handle is cast separately in the form of a sculpted figure of Charity nursing two babies; what is now a hole in the centre may once have been filled with the coat of arms of the original owner for whom this masterpiece was made.

Showing an independence of mind and a connoisseur’s eye, Baron Ferdinand Rothschild was the first to attribute the bell to Wenzel Jamnitzer by comparison with the Merkel tablepiece then in the collection of his cousin, Mayer Carl Rothschild in Frankfurt. Tiny reptiles and insects cast from nature crawling in the plants and grasses on the foot made it very likely that the same artist created the ‘Cellini bell’. Despite Baron Ferdinand’s perceptive attribution, the bell, with its close counterpart in the Munich Residenz, was only finally attributed to Wenzel Jamnitzer in the scholarly literature in 1967. It was published as such by the late Hugh Tait in 1988 [6; pp. 96–105]. Tait based his attribution on the evidence of the Munich bell, along with Jamnitzer’s designs for it and a plaster cast of a saddle-pommel from the Amerbach collection, made by Wenzel Jamnitzer and closely resembling both bell handles [6; pp. 100–101, 8; fig. 32, cat. 18 and 302]. The Munich bell is thought to be an ecclesiastical bell based on its engraved inscription from the Latin text of Psalm 49.

<table>
<thead>
<tr>
<th>Analysis position</th>
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<td></td>
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<td>Cu</td>
</tr>
<tr>
<td>HANDLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat side</td>
<td>96.5</td>
<td>3.3</td>
</tr>
<tr>
<td>Front; knee of left infant</td>
<td>93.9</td>
<td>5.8</td>
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<tr>
<td>Front; face of Charity</td>
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</tr>
<tr>
<td>Liner to perforation</td>
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<td>0.6</td>
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<td>Clapper</td>
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<tr>
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<td>Rim 4</td>
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<tr>
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<td>3.4</td>
</tr>
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<td>Body of bell 2</td>
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<tr>
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<tr>
<td>Front; seed on panel</td>
<td>93.3</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Figure 4. The inside of the bell showing concentric marks from turning and a dendritic structure in certain locations
Baron Ferdinand’s bell was important within his cabinet collection and he placed it at the centre of the table case reserved for his most precious Limoges enamels and microscopic boxwood carvings in the New Smoking Room at Waddesdon Manor. It can be seen clearly in one of the photographs in The Red Book of 1897, the privately published album that recorded every detail of Waddesdon as Baron Ferdinand’s personal creation [7; p. 199, fig. 3].

**Technical and analytical study**

The bell is composed of two main cast sections – the body and the handle – with a clapper inside the bell and a sheet silver liner to the perforation in the handle. The metal of which the bell was made was investigated using X-ray fluorescence (XRF) analysis with no preparation of the areas analysed, Table 1. The surface of the bell is very rough and often curves in two directions, making it far from ideal for analysis, therefore the results must be treated as semi-quantitative. As seen from Table 1, the four separate analyses on the smooth surface of the inside rim are more consistent than the results on the rest of the bell, suggesting a casting alloy composition of approximately 96% silver with a little under 4% copper and trace levels of less than 0.5% of both lead and gold.

The handle, which is soldered to the body of the bell, has a similar alloy composition to the body of the bell, but the batch for this melt contained higher trace levels of lead and a lower gold content, Table 1. The clapper, which is suspended from the inside of the handle (Figure 4), may also have been cast from this melt as the compositions are comparable. The handle has some post-casting features: a sheet silver insert to the perforation and a splash of a zinc-containing silver solder on the face of Charity. These features add support to the suggestion that the perforation may once have framed an insert such as a coat of arms. No evidence was found for the use of solder to join the animals or plants to the body of the bell itself, and every relief feature on the surface of the bell appears to be integral to the casting.

There are a number of historical references describing aspects of the moulding techniques used for life casting, such as lost wax and box casting; Smith and Beenjes have translated various parts of the French manuscript BnF Ms. Fr. 640 and refer to several other historical sources [1]. Flash lines caused by the flow of metal between the mould parts are present on some life-cast pieces [1; fig. 6], but none can be seen on the bell. There are, however, many undercuts in the creatures and plant decorations, so the absence of flash lines or chasing to disguise them makes it most likely that the bell was created using the lost wax method. The creatures and plants – together with additional elements modelled in wax such as the cartouches, baskets and lion masks – would have been applied to the surface of a wax bell and encased in a mould material before the wax and other organic material was burnt out. Manuscript BnF Ms. Fr. 640 suggests that the mould was heated to a high temperature to facilitate the flow of the molten silver into the complex cavities [1; p. 162]. The result is an object in which all the applied elements and the
The body of the bell comprises a single casting, with details from the real lizards, plants and other organic materials—such as cartouches and masks—copied faithfully into the silver, Figure 5. There are, however, some features that suggest a certain amount of work was carried out on the life-cast details after they were cast, such as chasing to remove casting fins (Figure 6a) and cutting or chasing to enhance areas on the shields, tops of the heads of lizards, part of the rope/chain along the rim and the snails, Figures 6b, 6c, 6d, 7a and 7b. In contrast, the creatures and plants for the automaton were cast individually and then soldered onto the hammered silver sheet that forms the mound, Figure 3.

**Surface finishes**

The surface of the silver on the bell has three different finishes or appearances: the body of the bell with animal and plant decorations has a rough textured finish (Figures 1 and 5c); the handle and small cartouches are smooth and matt white (Figures 1, 5d, 6c and 6d); and the high relief areas exhibit a smooth and reflective surface that is mainly attributable to wear, Figures 1, 5c and 6b. The outside of the bell body has a rough surface in which the dendritic cast structure of the metal is clearly visible. This prominent dendritic structure suggests that the surface was etched, although this is not evident from surface analysis of the metal. The etching of the surface is in many places very deep (Figures 7c and 7d), and the large size of the dendrites indicates a slow cooling rate for the cast. The dendrites in other silver life-cast pieces are not as prominent and have not been investigated, so it is not known to what extent slow cooling was a technique specific to life casting or if it was used here for some other reason, perhaps to control the tone of the bell.

The smooth areas of the cartouches have been created by cutting, or scraping over, the etched surface, Figure 6d. The matt white appearance seen on the surface of some areas of the bell is typically formed during what is described as blanching or whitening of silver, discussed below.

Because, in contrast to the body of the bell, neither the inside nor outside of the handle are etched, the bell must have been constructed from the handle and body after the latter had been etched. The inside of the bell wall has been turned to a smooth finish (Figure 4), although a dendritic structure is evident along the neck and adjacent to a soldered patch used to repair a casting fault on the shoulder, suggesting that the turning was carried out after etching.

**Etching and whitening**

The prominent dendritic structure seen on the surface of the bell could be the result of etching by exposure to a strong acid: Untracht recommends immersion without agitation in strong acids to reveal the crystal structure [13; p. 325], but the etching of the bell is extreme. The use of nitric acid is mentioned in several historical metalworking treatises, albeit not to create a surface texture as seen here. It has been suggested that etching

![Figure 6. Details of the life casts on the bell: (a) a toad with cut marks in its mouth and along its neck where a casting fin had been removed; (b) a snail with punch marks to imitate its texture; (c) the side of a shield with marks from chasing; and (d) a shield with chisel marks smoothing the surface after etching. The images were made using a Leica MZ12.5 microscope and stacked to enhance the depth of field using Leica LAS v4.2 software](image)
for silver may have been used mostly during the late sixteenth and early seventeenth century in Europe, especially in the German cities of Augsburg and Nuremberg [14; p. 74], and in 1547 Johann Neudorfer mentions that the brothers Wenzel and Albrecht Jamnitzer had taken silver etching to the highest level [8; p. 58]. It might be that the texture on the bell was created intentionally, either for its aesthetics or to create a surface to which a varnish would key, although there is no evidence that it ever had such a coating. It is possible, if not particularly likely, that the surface finish was an accidental effect of immersing the bell's body in acid after casting when trying to remove the mould material from the deep recesses under the life-cast features. Certainly no other comparable examples are known. Etching of the silver ground to create lettering in relief has been described by van Bennekom et al. for the Merkel tablepiece [15]. There are areas with a granular surface effect on both the Merkel tablepiece [14; fig. 43] and an ostrich-egg standing-cup attributed to the Jamnitzer workshop (WB.112) [16; pp. 43–51].

5 suggesting that etching may have been used to create textures. In these cases the textures are finer than on the bell but are used in a similar way to textures created using punches or engraving. A wider study would be needed to gain a fuller understanding of how the etching technique was applied and to what artistic effect.

The second aspect of the surface appearance is the matt white surface that is most obvious in the recesses and which commonly develops during pickling or ‘boiling out’ (see below), a process used to remove copper oxides and flux following soldering and annealing [13; pp. 416–421, 17; pp. 24, 63].

Treatises written between the sixteenth and the eighteenth century suggest similar treatments to attain the best colour of silver by a method described as blanching or whitening [18; pp. 360–365, 19; pp. 32 folio, 33, 36 and 56 folio, 20; pp. 88 and 106–109, 21; pp. 46–49, 22; pp. 17, 30 and 32]. The range of possible chemicals used in the process is mentioned in historical treatises, for example Biringuccio states that “silver is whitened by boiling with tartar, common salt, and, if desired with some rock alum” [18; p. 365, 21; p. 46]. The removal of the copper from the surface creates a slight surface enrichment in silver and a change in the tone of colour; in the replicas made by Meddeler, the enriched surface is 4 µm thick [14; p. 59, fig. 22]. After whitening, the surface would generally have been burnished or polished to present a highly reflective surface. In the case of the bell, no overall burnishing would have been possible and only some details, as described above, present a bright finish. This effect can also be seen on silver filigree, described by Untracht as dead-white [13; p. 179], where the raised areas are burnished and the matt white surface remains in the recesses.

There are, therefore, two possibilities for the original appearance of life castings. First, the realistically painted animals and plants, the production methods for which were described in manuscript BnF Ms. Fr. 640 and that are still present on pieces by Jamnitzer [1, 2, 9]. On the other hand there exists a portrait of Wenzel Jamnitzer showing a white bouquet in a vase in the background and a writing casket with life castings that has a ‘dead-white’ surface. Exactly how white the surface was intended to appear (i.e. plain as-cast or deliberately whitened) and how it was intended to be maintained are not clear from historical manuscripts. The description that most clearly indicates a matt white finish for life-cast silver plants is given by Smith in 1770: “anoint the silver plant with
oils of tartar, lay it on live coals, neal it, and then boil it in tartar, to which you add a little salt, and this will give it a fine bright pearl colour” [22; p. 106]. Other sources mention methods, either chemical or mechanical, to clean silver in general and the former are also often applied in the whitening of the metal, as Klein specifically states: “zu reinigen und weiß zu machen, hat man verschiedene Wege. Der beste Weg schwarzes oder stark angelaufenes Silber zu reinigen und recht weiß zu machen, ist das Absieden” [21; p. 46], which translates as: “there are different ways to clean and to make white. The best way to clean black or very tarnished silver and make it really white is ‘boiling out’”. These different silver surface effects, which result from the way in which the material was worked and treated, need to be taken into account when considering the most appropriate conservation treatments for the object.

Condition
In 2011 the surface showed little tarnish (grey-brown in colour) and some white deposits (mostly along or near the rim) that are thought to be residues from a protective coating; these luminesced yellow when illuminated with UV radiation at either 254 or 365 nm, Figure 8. No traces or other evidence of the surface having been previously painted were observed. Earlier treatments recorded in the Museum’s conservation dossiers date from 1971, 1984, 1991 and 1994. Most involved the removal of dust and tarnish from the surface using Hotel Silver Dip although the record of the 1971 treatment indicates that a Frigilene® (cellulose nitrate) coating was removed and reapplied.

Treatment
Having established that there were no original paints or coatings, the treatment undertaken in 2011 consisted of immersion in acetone and brushing the surface with a soft (squirrel-hair) brush to remove the old protective coating. The interior was cleaned with cotton wool soaked in acetone. Examination under UV light revealed that the majority of the white residue was still present after the solvent treatment. The surface was then treated using a steam cleaner, which removed all but a few traces of the residue (as detected by a faint UV luminescence). A long hog-hair brush was brushed over the surface to ‘revive’ the sheen on the slightly worn and thus burnished top surfaces in order to enhance the three-dimensionality of the relief. After almost 30 months on display it was noticed that the tarnish had redeveloped, most noticeably on one side of the object, a phenomenon that was thought to be associated with the airflow within an ageing display cabinet. A decision was made to remove the tarnish to expose the whitened silver surface as the bell was to be photographed for publication, and in preparation for a redisplay of the Waddesdon Bequest. Minimally interventive methods were first tested, including brushing with solvents and steam cleaning, but these did not give satisfactory results. The tarnish was successfully removed using Hotel Silver Dip applied on a squirrel-hair brush. Any residues were removed using a combination of steam cleaning and immersion in running tap water.

Conclusions
Both the automaton and the bell are examples of virtuoso work by Renaissance goldsmiths in Nuremberg. Following a long and eventful collection history, they have been held by the British Museum since 1898 and feature in a permanent display in the newly refurbished gallery dedicated to the Waddesdon Bequest.

Technical and analytical study of the objects has elucidated features of their manufacture including life casting, chasing and various aspects of the surface appearance. Of particular interest are the deeply etched surface on the body of the bell and its overall whitened appearance. No life castings with a similar etched surface are known, yet this texture on the bell is thought to be original, based on the evidence for the sequence of manufacture. There may be various explanations for such an etched surface: it may have been created accidentally during the removal of the mould or intentionally, either to provide keying for a varnish layer or to produce a specific surface texture. Although the technique of etching silver was known and used by Jamnitzer, it is currently unclear whether the technique was used more widely at this period to create surface texture; further research may help to provide an answer.

The absence of any traces of a naturalistic varnish or paint led to the decision to remove the tarnish from the life-cast silver elements with the aim of presenting the matt white surface. Because of the fragile nature of the life-cast elements and filigree surfaces, mechanical polishing would not have been possible during the manufacturing process and is not appropriate in the conservation of these objects, leading to the decision to use chemical methods to remove the tarnish from the surface and recessed areas. Within the automaton the mechanism has been cleaned to aid its long-term preservation, but the greatest changes are to the appearance of the surfaces of the bell and automaton, which are now displayed alongside the remainder of the Waddesdon Bequest in their full splendour.

Experimental appendix
The semi-quantitative composition of the metal of the bell was obtained using a Bruker ARTAX μXRF spectrometer with a molybdenum tube operating at a voltage of 50 kV and current of 500 μA. The beam was focused using a 0.63 mm diameter collimator and 300 seconds counting time at a number of 22 | Maickel van Bellegem, Dora Thornton, Paul Buck and Susan La Niece
Materials and suppliers

• Cotton wool: Synergy Health UK Ltd, 1 Western Avenue, Matrix Park, Chorley PR7 7NB, UK.
• Acetone, IMS and white spirits: VWR International Ltd, Hunter Centre, Northampton NN3 8PD, UK.
• Goddard’s Hotel Silver Dip: Johnson Diversey, Weston Favell Centre, Northampton NN3 8PD, UK.
• Silvo® silver and chrome wadding polish: Reckitt Benckiser (UK) Ltd, Delta Business Park, Swindon SN5 7XZ, UK.

Authors

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References


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Notes

1. The line drawing of the mechanism was reproduced in [5; p. 307] and can also be found on the British Museum Collection Online database, www.britishmuseum.org/research/collection_online/collection_object_details.aspx?partid=18&assetid=1290962000&objectid=40659 (accessed 29 April 2015).
2. Pyrhousa aptera, a common European species: http://en.wikipedia.org/wiki/Firebug (accessed 29 April 2015). The authors are grateful to Darren Mann, Timothy Wilson and Mark Norman for the identification of identical beetles on the ‘Welby cup’ in the collection of the Ashmolean Museum, Oxford, which was made available for examination during a study visit in 2013.
3. The tablepiece, now in the Rijksmuseum, Amsterdam, is a documented work purchased directly from Wenzel Jammitzer by the city of Nuremberg in 1549, see [8; cat. 13].
4. The texture on the surface of the bell was a point of discussion during the study day in 2012.
6. While pickling was a common technique historically, in more recent times the approach adopted by goldsmiths has been to prevent oxidation of the copper during soldering or annealing by covering the entire surface with a flux and then polishing away the resulting ‘fire-stains’, see [13; pp. 416–417, 17; pp. 265–266].
7. For the portrait in the Musee d’art et d’histoire, Ville de Geneve, see [8; p. 174]. For the writing box in the Kunsthistorisches Museum, Vienna, see http://bildenbank.khm.at/viewArtefact?id=919688&image=KK_1155_05.jpg (accessed 29 April 2015).
8. Alternative methods that are not abrasive and could be considered include the use of chelating agents or electrolytic reduction. A comparison of the advantages and disadvantages of these methods goes beyond the scope of this contribution.
The conservation and technical investigation of a hollow-cast Egyptian bronze

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SUMMARY A publication is being prepared that describes the investigation of the British Museum’s collection of large-scale Egyptian bronzes from the Third Intermediate Period. These bronzes, along with others from collections around Europe, are thought to have a common origin in the temple of Karnak in modern-day Luxor. Several of them are linked to the Greek agent d’Athanasi who recorded finding a cache of statues beneath the temple floor in the 1820s.

One of these bronzes (EA60718) was, however, found to be in a physically unstable condition, which endangered the object and hindered its investigation for the publication. Previous restoration was not to the standards of contemporary conservation and had to be removed in order to stabilize the object. The old restoration materials were analysed using Fourier transform infrared spectroscopy and removed where necessary. The conservation treatment described here consisted of reconstructing the object to stabilize it physically in a manner that will allow it to be deconstructed again easily in the future.

The conservation process also allowed more of the internal surface of the statue to be examined and brought to light new evidence of its manufacture. A detailed examination of the surface decoration was also carried out, which showed that it consists of gesso and gilding, inlays for the eyes, eyebrows and beard strap, as well as textile preserved within the metal corrosion products. The inlays were identified as lapis lazuli using Raman spectroscopy and the gilding was analysed with X-ray fluorescence spectroscopy.

Introduction

A publication is being prepared that describes the results from the investigation of large-scale Egyptian bronze statues from the Third Intermediate Period (c.1070–664 BC). There are examples of such statues preserved in Paris, Berlin, Leiden and Athens, but the largest collection of surviving statues can be found in the British Museum (BM). The BM statues consist of: three striding female figures (EA43371–EA43373); two Osiris statues (EA60718 and EA60719); and a male figure that is fragmentary and catalogued as EA22784 (the head and torso) and EA71459 (the feet). The statues of female figures and Osiris entered the collection of the BM in the 1830s and the male statue was acquired in 1889 [1; p. 9].

Apart from statue EA22784/EA71459, which is thought to have been found at Giza, these figures all came to light in the 1820s and 1830s during a period when European diplomats and their agents were able to excavate and collect objects unrestrictedly with the permission of the ruler of Egypt, Mohammed Ali. Giovanni d’Athanasi, who acted as collecting agent for Henry Salt, the British consul in Egypt, recorded finding a cache of objects at Karnak: “which opened a rich store of valuable curiosities to our view: - amongst which were several statues of bronze and stone of various shapes and dimensions” [2; p. 67]. Temple statues are known to have been deliberately buried beneath temple courts once they had fallen out of use, as exemplified by the great Karnak cachette discovered in 1903 [1; p. 14].

D’Athanasi began to work for Henry Salt in 1819. The last objects collected by Salt between 1824 and his death in 1827 were transported to England and auctioned at Sotheby’s in London in 1835, with the BM purchasing many of the most important objects [2; pp. 149–151], including EA60718, EA60719 and EA43372 [3]. It is perhaps significant that a comparable female figure in bronze was included in an earlier
collection formed by d’Athanasi for Salt and is now in the Musée du Louvre [4], while the most famous example in this series of bronzes – the statue of Karomama (Louvre N.500) – had also originally been in d’Athanasi’s possession. Statues EA43371 and EA43373 entered the BM in 1839 via the collection of the Swedish-Norwegian consul Giovanni Anastasi, who had obtained the bulk of his objects through an agent based at Qurna, opposite Karnak [1; p. 14]. It is perfectly possible, therefore, that these figures have a common origin, perhaps from a cache beneath the temple floors at Karnak.

Some of the statues would probably have been installed in the small chapels within the complex of the temple of Amun-Re at Karnak, and may have formed part of the accoutrements of the sacred barques on which the images of deities were carried in procession at religious festivals. An inscription on the statue of Karomama alludes to her function as the god’s ‘pilot’, supporting this hypothesis [5]. Karomama’s statue can be dated by inscriptions to the Twenty-second Dynasty, the mid-point of the Third Intermediate Period, and stylistic evidence indicates that all the other statues considered here belong within the confines of this period, from the mid-eleventh to the mid-seventh century BC.

When the BM bronzes were being examined for the publication, statue EA60718 was found to be in a physically unstable condition, which made it difficult to move safely and investigate fully for publication, Figure 1. In order to recover as much information from the object as possible, investigative conservation of the statue was required alongside technical examination and analytical study. This contribution presents information on the manufacture and surface decoration of this object, describes the materials and methods of previous restorations and details the recent de-restoration and conservation treatment.

Description
Statue EA60718 depicts the mummified god Osiris. His hands, folded across his chest, would originally have been holding a crook and flail of which only the former remains [1; p. 11]. He has the customary atef crown, the central element of which is the ‘white crown’ of Upper Egypt. Representations of ostrich feathers would have been attached at each side and a pair of ram’s horns perhaps projected from the base of the crown above the ears. These are now missing but remnants of the mechanical fixings or tangs used to attach them are still present. Originally standing around a metre in height, the statue is now 97 cm in length from the bottom of the basal tang to the top of the damaged crown. The entire main body casting is hollow and open at the feet where only one side of the basal tang remains. The end of the crown, which would have been bulbous in shape or have had a separate spherical feature, is now missing. There would also have been a beard, most probably inlaid in a manner similar to that of the surviving chinstrap. A collar is represented around the neck.

Manufacture
The statue is of bronze but due to the corroded state of the metal it was only possible to obtain one sample from the main casting in a reasonably metallic state, and even in this case the analytical totals were low due to the presence of corrosion products. Another sample was taken from the stub of the tang of the proper right hand feather. Both sample drillings were analysed by inductively coupled plasma-atomic emission spectroscopy (ICP-AES) [6]. The main body of the casting is of bronze with 2.5% tin and 19% lead. The other statues analysed as part of this project have a wide range of compositions but alloys with a low tin content and high lead content are not uncommon. Where it was feasible to sample statues at a number of points, for example in the torso of EA43372, it was possible to see the massive gravity segregation that occurred when much of the lead sank to the bottom of the casting while the metal set in the mould. For significant segregation to occur, however, the walls of the casting usually have to be quite thick, whereas here they are thin and the lead would have had difficulty flowing through the narrow space. A closer parallel is found in the thin casting
of statue EA60719, where multiple sampling was possible and showed that a high lead content was maintained throughout the casting. This suggests that the single analysis of EA60718 is likely to be reasonably representative of the whole. The sample from the feather tang was of copper with only 0.6% lead and a level of tin below the detection limit of 0.1%. This composition suggests that the feathers may well have been wrought rather than cast, and that they would have appeared coppery red in contrast to the rather grey metal of the main casting.

The statue comprises a single casting from head to tang with a separately cast headdress. The feathers and insignia were also separate, although the surviving crook is now firmly attached to the hand that grasps it by corrosion (see below). In common with the other statues examined as part of this project and many further figures of the Third Intermediate Period [1, 7, 8], the body is a hollow lost wax casting. The statue was cast around a core of sandy clay, much of which survives. In some statuary the core was built around an iron armature (e.g. EA43371), but examination of the X-radiographs for EA60718 and direct inspection of the core in the lower part of the torso show that no armature is present inside this statue.

Previous work on these statues indicated that they were all likely to have been direct hollow lost wax castings [1], but continuing research (to be published as a British Museum Research Publication) has shown that the situation is more complex. Some figures (EA43371–43373) were made by the direct process, in which the wax was applied to the core, moulded and cast. Others (EA60719 and the statue considered here) are likely to have been cast by the indirect process. In this process an original object was moulded with plaster of Paris in sections that, after moulding, could be taken apart and removed from the original. Wax could be impressed into the resulting negative mould sections to create a set of wax sections that would have been assembled to form a hollow wax positive. Core material was then inserted the hollow and the casting proceeded as with the direct process.

The wax sections would have been held together with molten wax. On the outside face of the wax all trace of the join would have been removed prior to moulding to ensure a smooth, uninterrupted outer surface on the cast bronze. On the inner face, which would not be visible, there would have been no need for such finishing and here lines of thickening, where a wax-to-wax join was made, are clear evidence of the indirect process. The broken and open bottom of EA60718 provided a good opportunity for examination and a line of thickening was clearly visible beneath the feet suggesting a join where the feet, moulded in two halves, have been joined, Figure 2a. Inside the feet there is another line of thickening running horizontally at about ankle level where the feet assembly was then joined to the wax of the main torso, Figure 2b.

Castings produced by the indirect process tend to show a much more uniform metal thickness than those made by the direct method; the rather thin (typically no more than 2–3 mm) and uniform thickness of the casting in EA60718 provided support for it being an indirect lost wax casting. In addition, the nearest comparative statue, EA60719, is also believed to be an indirect casting. This technique, an innovation of the Third Intermediate Period, was later to be adopted by the Greeks as the foundation of their casting technology for major statuary.

Surface decoration

Gilding

There are remnants of gesso and gilding on the collar, neck, face and crown (Figure 3), suggesting that these areas would once have been completely gilt. Unlike the similar Osiris figure (EA60719), no traces of gesso or gilding are present elsewhere on the body. Gold was of great importance to the ancient Egyptians; it was associated with immortality and was used frequently in their funerary practices. The skin of the gods was described as ‘gold’ in some sources and from the Middle Kingdom onwards coffins and mummy masks had gilded faces and hands or skin painted yellow to imitate gold [9; p. 29].

The Egyptian method of gilding bronzes by first applying layers of gesso is unique and was probably carried over from their methods for gilding wooden objects; Egyptian technology often used similar techniques with different materials to achieve comparable effects [10; p. 54]. Gesso consists of a white filler material bound in an organic medium and evidence for both animal glue and plant gum binders has been reported in previous studies [9; p. 45]. The gesso on statue EA60718 had been analysed previously and found to contain gypsum.
(calcium sulphate dihydrate) with some impurities (i.e. a true gesso), although calcite (calcium carbonate) is also commonly present on other examples in the BM [11; pp. 36–37].

X-ray fluorescence (XRF) analysis on the unprepared surface of a sample of the gold leaf from EA60718 gave results of 98.3% gold, 1.4% silver and 0.3% copper. This high purity may be indicative of refined gold, although there is very little evidence for gold refinement in Egypt before the Late Period (664–332 BC) [12; p. 163]. Reliefs from the tomb of Baqt at Beni Hasan dating from c.1900 BC, which show the washing and refining of crushed ore, seem to indicate that it was known if not widely used [12; p. 162]. In addition, native gold has been found in Egypt with a purity greater than 90% [9; pp. 29–30], so it is impossible to say whether this leaf is refined gold.

Pure gold is not required to make gold leaf – indeed samples with a purity as low as 78.7% have been found [9; p. 30]. Leaf was manufactured by hammering gold foil between sheets of goldbeaters’ skin (ox intestine). It could then be attached with an adhesive in small overlapping sections and burnished carefully [11; p. 38]. Animal glue and albumen (egg white) have been suggested as probable adhesives and solubility tests carried out by Lucas pointed towards the use of animal glue [10; p. 52].

Figure 3. Maps of EA60718 showing the extent of surviving gesso (pale grey areas) and gilding (yellow areas) on: (a) the front of the head; and (b) the back of the head

Figure 4. Inlaid crooks: (a) from the figure of Osiris EA60718; and (b) an inlaid, gilded copper alloy crook (EA60730)
Inlays

The chinstrap and eyebrows are represented by inlays and the inlaid material was identified as lapis lazuli using Raman spectroscopy. Only small fragments of the inlays remain but the channels containing the cement used to hold them in place are still present. Lapis lazuli was used as an inlay from the Naqada I period (c. 4000–3500 bc) and was probably sourced from the region of Badakhshan in north east Afghanistan as there are no known sources in Egypt [13; p. 39]. The use of blue alongside gold on statuary and paintings is well known in Egypt and this combination of colors had distinct symbolic meaning [14; p. 103].

The eyes are inlaid, a practice seen frequently on coffins, mummies and mummy masks as well as bronze sculpture [15; p. 98]. The borders of the eyes are also inlaid using lapis lazuli with a white fill in the centre, which may represent the eyeball but may equally be cement used to hold an eyeball insert in place. The eyeball would typically have been made from crystalline limestone, although other materials found in this context include white opaque quartz, glass or bone. A hole would have been left in the centre for the pupil, normally made from obsidian, but with black resin, limestone or glass also used [15; p. 108]. As even small statuettes contain very detailed and often intricate eyes, their depiction was clearly of great importance in ancient Egypt [16; p. 51].

On the crook, the individual cells that originally contained inlays are visible (Figure 4a), giving it a characteristic striped effect. An X-radiograph of the crook shows a regular pattern of equal-sized cells with no evidence for additional metal inlays. Some traces of blue and red material are visible towards the bottom of the crook, which may correspond to original inlays of red and blue glass; a miniature crook in the BM collection (EA60730: Figure 4b) gives an indication of how the crook on EA60718 might once have appeared. It is also possible that the surviving traces of colour are the remnants of coloured fixing cements for lapidary work. The use of different coloured cements implies the use of at least two contrasting colours, perhaps stones such as carnelian, lapis or turquoise.

Textile

Evidence of textiles has been preserved within the corrosion products on the surface of the bronze. Mapping the locations at which evidence of this mineral-preserved textile occurs across the figure suggests that the entire surface was covered below the gilt collar, Figures 5a and 5b. Unfortunately the textile at the neckline is in poor condition so no obvious edges

![Figure 5. Maps of EA60718 showing the extent of surviving textile remains (pale olive areas) on: (a) the front of the statue; and (b) the back of the statue](image-url)
can be observed. Since the figure of Osiris is typically shown as mummiform in two- and three-dimensional Egyptian objects, it seems likely that the lower part of this sculpture was wrapped in textile as though it was a mummy, with the total absence of textile above the neckline strongly suggesting that the crown, head and neck were not wrapped. In addition, there is no preserved textile on the crook, suggesting that the regalia elements were added after the wrapping. This evidence all points to the wrapping being carried out for the statue’s life rather than its interment. This argument is supported by the large wooden Osiris (EA51092: Figure 6), which also has a layer of linen textile (Linum usitatissimum) with a dark resinous coating that does not cover its gilded face, crown and neck.

Although much textile remains on the surface of EA60718, it is poorly preserved and is likely to have been linen, the most common Egyptian textile. Only one layer of textile is visible, probably applied with an adhesive although no traces of this remain on the surface. The textile shows a simple tabby or plain weave with single warp and weft threads, a pattern that has been used for linen in many cultures over the millennia [17; p. 41]. Although the linen is a close match for mummy bandages, the textile edges can rarely be seen, making it impossible to gauge the exact width and size accurately. The best edge is on the back of the ankles, but the preservation is not sufficient to assess how the edge was manufactured, Figure 7c.

Most of the textile has a very open weave (Figure 7a), but the thread count and the thickness of the threads vary across the surface of the object, as does the thickness of the thread. While this could indicate that several different textiles were used to wrap the object, comparable preserved Egyptian linen textiles from a similar period show similar inhomogeneity, Figure 7b. Thread thickness and count will also depend on the extent to which the textile was stretched.

In the case of EA60718 there is no evidence of textile present beneath the gesso layer, which would have been applied to the sculpture to act as a key for the wet gesso, a phenomenon observed on other statues, for example the female striding figure in the Louvre (N3390) [4; p. 139, 10; p. 53]. A comparison with EA60719, a mummiform Osiris of similar form, is also valuable. There is evidence of gesso and gilding on this statue, both above and below the collar line, although below the neck it only survives to any extent on the arms and hands. There is no evidence for textile anywhere on the surface, which suggests that this Osiris figure was not wrapped in the manner of EA60718.

**Previous restorations**

As the entry for EA60718 in the *Catalogue of additions made to the Department of Antiquities in the year 1835* states that “the head is broken off” [3], it is clear that it must have been reattached after the statue arrived at the BM. No other breaks or damage are mentioned specifically, but both the *Catalogue of additions… and the ‘Birch slips’, written by Samuel Birch from the late 1830s onwards* [18; p. 15], mention the presence of “two ostrich feathers, one on each side, placed on the horns...
of a goat”. The Birch slips also mention: “the atef consisting of the conical cap surmounted by ball” [18; p. 15]. There is a strong possibility, therefore, that an accident befell this object at the BM, resulting in the loss of the feathers and the tip of the crown as well as further breaks in the object; the damaged edges of the feather tangs are almost totally corroded and would have broken very easily. The flail is confirmed as missing in all these sources and, as the space inside the hand that once gripped the missing flail is now completely blocked with corrosion, it seems likely that it was lost in antiquity.

In November 1836 the BM decided to engage John Doubleday, now best known for his restoration of the Portland Vase in the 1840s, to undertake “cleaning, repairing and fixing upon pedestals the Egyptian objects lately purchased, and such of the old collection of bronzes, as may require it” [19; p. 4390]. As this figure had been lately purchased and has certainly been restored since excavation it seems likely that it is one of the figures on which Doubleday worked.

Three breaks run through the object at the level of the ankles, knees and neck. A piece of softwood had been inserted in the basal tang and feet to the knees and it is probable that the core material was removed from the legs to allow this. A square-section brass rod with regular notches cut into it was pushed into the remains of the core at the knees and plastered into the bottom of the wooden block. A yellow fill material was then poured into the legs to fill any remaining space and hold the wooden block firmly in place; droplets on the surface provide evidence that this material was applied in a molten state. The wooden block was also held in place by two iron nails, one through a hole in the basal tang and the other through the back of the proper left leg. Garland and Bannister, who worked on the restoration of early Egyptian bronzes, mention the use of plaster and dowels to keep broken hollow-cast bronzes together in a similar fashion [20; p. 200].

There are many other cracks and missing areas throughout the bronze, which are filled with plaster and/or the yellow fill and painted to match the corroded metal surface. At the broken top of the crown it appears that the yellow fill has been poured inside to stabilize this area and, where visible, has been painted to match the surrounding surface.

The head tilts to the right and does not appear to be seated properly on the shoulders; currently the neck’s upper break edge overlaps the lower edge on the proper right side. The X-radiographs suggest that there may also be a wooden dowel in the neck to support this join with what appears to be wood grain visible in the image, Figure 8a. Another X-radiograph shows a void in the same area (Figure 8b), suggesting that the core was removed, although only as much as necessary to insert the dowel. X-radiography was carried out on the block of wood from the legs in order to examine whether the grain would be visible from different directions. This showed that it would only be visible from one direction and that wooden inserts might not, therefore, be easily detected when conducting X-radiography. As the join at the neck seems to have been repaired in a similar manner to the break at the knees there is a good chance they were carried out at the same time.

As suggested by the extent to which textile remnants survive, little cleaning has taken place on this object. In the nineteenth and early twentieth century small hammers and chisels were commonly used to remove corrosion from bronzes, while other methods, such as技术 of removing corrosion from bronzes, while other methods, such as solutions and brushing, were also employed. Some of these techniques were destructive and could result in the loss of surface detail.

Recent conservation treatment

Condition before conservation

Conservation work was required as the statue was no longer stable. In particular a mobile gap with a width of c.1 cm had opened up at the knees; the movement of this joint was threatening to damage the break edges and made lifting the statue dangerous. The conservation work required to address the stability of the statue also provided an opportunity to investigate the old restoration methods and allowed access to examine the interior.

The statue is almost totally mineralized with only small remnants of metal visible in cross-section. There has been some delamination of the surface revealing different layers of corrosion but there is no suggestion of recent chemical instability. Unusually for an Egyptian bronze excavated in the nineteenth century, burial soil and concretions are still present on the surface of the figure, notably on the crook and back.

Scientific investigation of early restoration materials

Prior to conservation treatment, the materials used in the earlier restorations were identified in order to inform their safe removal or reduction. The yellow fill from the legs was sampled and analysed using Fourier transform infrared (FTIR) spectroscopy. Its major constituent was found to be beeswax, which had been mixed with a number of inorganic compounds, principally plaster of Paris (calcium sulphate dihydrate) and silica to which some natural resin had been added [22; p. 3]. The resins that might have been used in a historical restoration of this period include dammar, mastic and shellac, as recommended by both Rathgen and Lucas [23;...
Beeswax was commonly used as a coating or consolidant for copper alloys [23; p. 222, 24; p. 40]. As it can promote further corrosion through the formation of copper soaps [25; p. 332], it was considered best to remove as much of the fills as possible.

While there are a number of examples of the use of wax in such restorations, including the application of pigmented wax containing natural resins to cover flaws in the surface of Egyptian bronzes at the Brooklyn Museum [26; pp. 98–99], it is unusual to fill such large voids with this material, as was the case for this Osiris statue.

De-restoration and conservation

Although the join at the knees appeared to be very loose, it could not be coaxed apart with gentle movement and the angular break edges hindered this process so that further movement risked causing additional damage. Solvents were used in an attempt to loosen the dowel but they were not effective, leaving the only option of investigating the join from the open area at the bottom of the feet.

As beeswax melts at around 60°C the yellow fill could be removed mechanically after gentle heating, which allowed the legs to be removed carefully. It became clear that the dowel had been held in place by plastering one end into a slot carved into the wooden insert (Figure 9a) and the other end into the remaining core material in the top half of the statue, Figure 9b. A slight bend in the dowel had prevented its removal while the fill was still in place.

Despite evidence suggesting that the head is not correctly seated, a decision was taken not to remove and reseat it, as the current join appears to be stable and the object is not scheduled for display in the near future.

To investigate the crook for further evidence of coloured inlays the remaining burial concretion was removed using a sharp scalpel under an optical microscope. This further cleaning revealed more areas of red and yellow/white deposits, but these were not analysed as they were suspected to be heavily contaminated by copper corrosion products [27].

To support the statue the wooden dowel was replaced with a high-density Plastazote (polyethylene foam) support of similar size. Large gaps were filled with fibreglass moulded to the correct shape and attached with HMG heatproof and waterproof adhesive (cellulose nitrate). The fibreglass gap-fills were designed so that they can be removed easily to allow access to the interior in the future. Smaller fills were made using Paraloid B72 mixed with glass microballoons, while the same HMG adhesive was used to repair cracks. The statue after reconstruction can be seen in Figure 10.
Conclusions
This de-restoration and treatment has allowed access to the interior of the statue of Osiris and offered the opportunity to study the surface closely, providing more information on the object’s materials, manufacture and subsequent history. It has also stabilized the object, reducing the risk of future damage. In contrast to the restorations carried out in the nineteenth and early twentieth century, the latest treatment is easily reversible, which will allow the object to be studied in greater depth in the future.

Carrying out this de-restoration also allowed a more detailed study of early treatment methods. While there is no way of knowing for certain whether this restoration was carried out by John Doubleday, the evidence from the archives suggests that he worked on this statue. There are also direct comparisons with treatments carried out on Egyptian bronzes in other collections and it is hoped that, taken alongside those reports [20; p. 200], this study will help to provide a better understanding of nineteenth-century restorations of ancient Egyptian objects.

The treatment of this statue has highlighted the importance of making and keeping appropriate records of conservation interventions. No treatment can be expected to last forever and it is far easier to remove old conservation materials when their composition and method of application are known and documented.

There is potential for further cleaning of the surface, especially on the back of the figure where considerable amounts of burial dirt are still present that appear to cover further mineral-preserved textile. As this figure is currently in storage resting on its back, the dirt and corrosion serve to protect the textile from damage to some extent, but if the statue were to be returned to its standing state – perhaps for display – further cleaning could be envisaged. This might provide additional information on the manufacture of the textile should it prove to be in better condition in this region. Further cleaning of the areas where gilding and gesso have been lost may also resolve whether keying is present and the method of its execution.

Additional cleaning was not, however, undertaken as part of this treatment as its primary aims were to stabilize the statue for future storage and to allow it to be investigated as part of the study of its original materials and techniques. It is rare now to find an Egyptian bronze left uncleaned and, as cleaning is an irreversible process, there is an argument for allowing this statue to remain as an example of the condition of an excavated bronze [28; p. 113]. Should further cleaning be undertaken, consideration might also be given to adopting the practice of leaving a small portion of the figure uncleaned to show a full corrosion stratigraphy as an aid to any future surface investigation [28; pp. 102–103].

The links between this Osiris figure, related statues and their burial site might be further investigated. Although currently not a method that yields useful results, the analysis of the soil deposits may potentially provide further evidence for the find spot of this and associated bronze figures. Another avenue for investigation might be the corrosion scars on this and other statues thought to be buried together [29]. If they were buried in contact with each other they may have corroded together and it is possible that tool marks may be present that suggest their separation and thus provide evidence of a common origin.

Experimental appendix

FTIR spectroscopy
A fragment of the yellow filling material was separated into two samples prior to analysis. The first was used to investigate the composition of the whole sample, while the second was extracted with dichloromethane (DCM) to allow more detailed identification of the organic and inorganic components. After one hour, the DCM solution was decanted and those components that had not dissolved were left to dry prior to analysis. The first sample was ground to a homogeneous mixture and attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectra were acquired using a Smart iTR diamond accessory on a Nicolet 6700 spectrometer. Spectra were acquired over the range 4000–550 cm$^{-1}$ using 32 scans at a resolution of 4 cm$^{-1}$ and automatic gain. The same procedure was used to analyse the insoluble components of the second sample after they had dried.

A few drops of the fraction of the second sample that was soluble in DCM were left to dry on an aluminium-coated slide and analysed using the Nicolet 6700 spectrometer coupled to a Continuum IR microscope (Cassegrain ×15 objective and MCT/A detector). The interferograms were collected in reflection mode over 64 scans at a resolution of 4 cm$^{-1}$ in the spectral range 4000–650 cm$^{-1}$. Identifications were made by comparison with the spectrometer’s inbuilt databases.

Inductively coupled plasma-atomic emission spectroscopy (ICP-AES)
Samples of metal were drilled from discreet areas of the figure using a size 60 hardened steel drill bit. The samples were dissolved in aqua regia (a 1:3 mixture of concentrated nitric acid and concentrated hydrochloric acid) and analysed using an ARL 3410 ICP-AES.

Raman spectroscopy
Raman spectra were obtained using a Jobin Yvon LabRam Infinity spectroscope with a green (532 nm) laser with a maximum power of 2.4 mW at the sample, a liquid nitrogen cooled CCD detector and an Olympus microscope system. Spectra were collected for between two and three minutes and were identified by comparison with a British Museum in-house database.

X-radiography
The majority of the X-radiographs were taken using a Sievert Isovolt DS1 X-ray tube held within a lead enclosure. For film X-radiography Kodak Industrex MX and AA films were used with voltages of between 170 and 200 kV and an exposure of 35 mA minutes. The film X-radiographs were scanned using an Agfa RadView digitizer with a 50 µm pixel size and 12-bit resolution in order to allow digital manipulation and enhancement of the images.

More recent X-radiographs were taken using a Comet MXR225/21 tube head at 150 kV with exposures of 50 mA minutes and a 1.63 mm copper filter. The X-radiographs were digitized using a Carestream Industrex HPX-1 reader with a 50 µm pixel size and 12-bit resolution.
X-ray fluorescence analysis
The XRF analyses were carried out using a Bruker Artax spectrometer on uncleaned surfaces and should, therefore, be considered only as semi-quantitative as the results will be affected by the presence of surface alteration or corrosion. The spectrometer was fitted with a molybdenum X-ray tube operated at 50 kV and 0.8 mA. Spectra were collected for 200 seconds while analysing an area that was c.0.63 mm in diameter.

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• HMG cellulose nitrate adhesive, Paraloid B72 and Plastazote: Conservation Resources (UK) Ltd, Unit 2, Ashville Way, Off Watlington Road, Cowley, Oxford OX4 6TU, UK.

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Note
Developing a passive approach to the conservation of naturally mummified human remains from the Fourth Cataract region of the Nile Valley

Barbara Wills and Daniel Antoine

SUMMARY

Over 40 naturally mummified individuals recently excavated from cemetery sites in the Middle Nile Valley have been the focus of a two-year stabilization programme. Dating from the Medieval Christian period (sixth to fifteenth century AD), they were recovered as part of the Merowe Dam Archaeological Salvage Project in anticipation of the flooding caused by the construction of a dam at the Fourth Nile Cataract in Sudan. Along with a collection of over 1000 skeletal remains, these naturally mummified bodies were donated by the National Corporation for Antiquities and Museums (Sudan) to the Sudan Archaeological Research Society, which in turn presented them to the British Museum where they are now researched and curated. Naturally preserved by the arid desert environment, only a few examples from the Medieval period have survived. The mummies arrived at the Museum requiring extensive cleaning and were too fragile to allow a programme of study. A customized approach to conservation treatment and storage was required that would stabilize the remains without hindering present or future analyses. A significant amount of dedicated conservation time was needed, requiring resources not then available within the Department of Conservation and Scientific Research. Fortunately, the award of a Clothworkers’ Foundation Conservation Research Fellowship – entitled Safeguarding a body of evidence: researching and conserving a group of exceptional naturally-mummified Nilotic human remains (2011–2013) – provided the necessary support. The grant was used to research and develop appropriate passive stabilization methods, apply these techniques successfully and subsequently pass on the knowledge gained to others who have responsibility for similar collections.

Introduction

As outlined in its policy on human remains, the British Museum is committed to curating the human remains in its collection with care, respect and dignity [1]. Ancient human remains are an important record of past funerary belief and practices, and their analysis provides a wealth of information on past human biology and societies. The British Museum holds and cares for more than 6000 human remains, over 100 of which are mummies from the Nile Valley. Many of these mummies were recently recovered during the Merowe Dam Archaeological Salvage Project, prior to the completion of a new dam at the Fourth Nile Cataract in modern Sudan, Figure 1. As part of this major international rescue campaign, the Sudan Archaeological Research Society (SARS), in conjunction with the British Museum, excavated sites that are now submerged under a lake. Over 1000 human remains from Neolithic to Medieval sites were recovered and generously donated to SARS by the National Corporation for Antiquities and Museums (Sudan). SARS subsequently donated this collection to the British Museum, where it is now curated and is the focus of an extensive research programme. The analysis of this remarkable collection is providing a unique insight into the inhabitants of the Fourth Nile Cataract. More than 40 rare examples of mummies from the Medieval period that were naturally mummified and preserved by arid conditions were also recovered. These natural mummies have, over a two-year period, been the focus of an extensive conservation programme.

Archaeological background

The mummies came from three sites, designated 3-J-23, 3-J-18 and 4-M-142. Site 3-J-23 was identified in 1999 and
subsequently excavated over a number of seasons until 2007. Located on the left bank of the Nile and close to the modern village of et-Tereif, over 190 burials dating from the Post Meroitic period (fourth to sixth century AD) to the Christian period (sixth to fifteenth century AD) were excavated. Although some graves did not have funerary monuments, many were marked by box grave monuments on the surface covering ovoid-shaped tombs, oriented west to east, [2]. On Mis Island, site 3-J-18 was excavated over two seasons, Figure 2. Fewer than 180 burials were recovered and several of the natural mummies were found close to the remains of a church [3, 4].

At site 4-M-142, on the left bank of the Nile opposite Dirbi Island, several Medieval Christian box graves were discovered and excavated [5]. In all three sites the bodies appear to have been placed in an extended position directly on the soil within the grave cut, without coffins. Lintels made of stone sometimes covered, or partially covered, the remains within the grave: this would have allowed air to circulate and aid rapid desiccation.

Condition survey and description of the natural mummies

On arrival at the Museum most of the mummies were laid out on boards made of medium density fibreboard (MDF) and housed on adjustable metal racks in a dedicated human remains store. Several individuals were too fragile for removal from their transportation crates, Figure 3. All were in a post-excaivation state, soil-covered with much material remaining in bags and boxes. In March and April 2010 a survey was undertaken with the assistance of an intern and a student. Each mummified individual was, as far as was possible, examined, photographed, assessed for conservation needs and details of interest noted [6]. The priorities were to record condition and recommend improvements in storage.

The degree of preservation and loss differed not only from mummy to mummy but also within a single individual. The survival of soft tissues was generally partial although sometimes almost complete (when viewed superficially). Skin, hair, fingernails, toenails, tendons, cartilage and some internal organs were present to varying degrees. Bones and teeth, being more robust, tended to be in excellent condition. Unlike artificially
mummified remains, which often have dense and compact soft tissues and little evidence of insect attack, the soft tissues of these natural mummies were commonly found as separate, often brittle, layers. Voids between the different tissues – skin, tendons, organs, bones, for example – were evident, Figure 4. Insect attack had been frequent, shown by the presence of holes, termite channels and remnants of insect parts.

It appears that the decay processes had been halted at different stages in different bodies. In a warm environment, such as that of the Nile Valley, decomposition can proceed very swiftly, but the lack of moisture in the arid environment of northern Sudan can occasionally arrest decay. Generally, the lower abdomen was poorly preserved, while the upper parts of the head, shoulders and ribcage, and extremities such as feet and hands, tended to survive best. Large areas of contiguous skin and connective tissue often remained in place, covering the skeleton. However, in mummies where decay had progressed further, areas of tissue and wrappings were preserved but had detached from their original location, Figure 5. Internal organs such as brains and lung tissue occasionally survived [7]. Hair, from the head and elsewhere (including eyelashes and legs), was also preserved and the survival of the skin allowed tattoos and/or other skin modification to be seen [7, 8].

Most of the bodies were soil-covered (Figure 6), often soil-encrusted with occasional hard concreted layers that included stony material. In terms of stability, most had areas that were extremely fragile and fragmentary.

Many of the burial wrappings also remained intact and in place. These were usually plain-woven textiles made of linen and other vegetable fibres, wool or more rarely silk. The coverings were frequently secured by binding with cords made from various fibres, some of which included human hair. Two of the mummies were partially covered with prepared animal skins or leather. The mummy referred to as sk1110 (site 3-J-18)
Barbara Wills and Daniel Antoine

was clad in colourful woollen and silk garments and rested on a folded, multilayered skin or leather ‘cloak’. The inner skin/leather layer had a bright blue fleece of fine, curly wool that was approximately 60 mm in length. Skeleton 4431 (site 3-J-18) was wrapped in a garment made by stitching together several hair-on skin/leather pieces [9]; the ‘woolly’ side was on the interior. The two fleece colours, yellow-beige and dark brown, are similar in colour to the woollen textiles worn by the majority of the mummies [10].

The textile and skin/leather wrappings in close association with the undersides of the bodies were often decayed, stained and brittle, presumably through contact with the underlying soil and the pooling of bodily fluids. The preservation of the wrappings elsewhere was variable and ranged from poor to excellent; the textile colours remained bright and the fibres usually retained their flexibility. The areas of skin/leather varied from cracked and fragile to pliable and resilient.

Developing methods and procedures

The project clearly illustrated the conservator’s role, as described by Cassman and Odegaard [11], working as a facilitator or “contributing colleague” who is able to help stabilize a collection, note features, enable research and, if required, prepare items for loan or display. Although British Museum colleagues were central to its success, particularly those from the Department of Ancient Egypt and Sudan and the Department of Conservation and Scientific Research, advice was also sought from external specialists. As the conservation literature on the care of mummified remains usually focuses on intentional mummification [12, 13], little has been published on natural mummification, so additional research was needed.

Existing passive conservation storage methods and materials were examined alongside less familiar but potentially useful materials [14]. This included a range of supporting and cushioning fabrics, as well as an experimental Plastazote® (expanded polyethylene foam) sheet with a sealed – and hence smoother – surface that is less liable to trap dirt. However, the sealing process also gave the sheet greater rigidity with the consequent loss of some necessary cushioning qualities. Most of the experimental fabrics and supports were ultimately unsuitable, but those with greatest promise were selected, evaluated for use and tested to check for the emission of harmful gases.

The risks associated with fragile human remains, including handling for study, were considered at the outset so that appropriate protocols could be devised and conventions for sampling and recording methods discussed and agreed. A temporary studio adjacent to the stored human remains was set up and a successful bid made for funding to cover the costs of the materials that would be required to rehouse them. Throughout the process, current professional standards and best practices in both conservation and physical anthropology were observed [1].

Treatment and mounting

Although the remains had been surveyed in 2010, the conservation time and resources needed for treatment, stabilization and mounting were simply not available. Fortunately, the award of a Clothworkers’ Foundation Conservation Research Fellowship – entitled Safeguarding a body of evidence: researching and conserving a group of exceptional naturally-mummified Nilotic human remains – to one of the authors (BW) provided the necessary support for the project to go ahead in 2011–2013, see the appendix.

Cleaning, stabilizing and consolidating human remains often involve the application of extrinsic chemicals and materials that can potentially affect or limit future bioarchaeological analyses [15]. Predicting the short- or long-term impact of any such conservation treatments can be difficult as some current analytical methods, including ancient DNA or stable isotope analysis, were not available two decades ago [16].
Well-established methods, such as radiocarbon dating, are also constantly evolving, being superseded or revised, and are often affected by the presence of external contaminants [16]. Mindful of the potential importance of as-yet undeveloped analytic techniques and how these may significantly further our understanding of the inhabitants of the Fourth Cataract, a central aim of the project was to develop a system of passive conservation that avoided the use of solvents, adhesives or consolidants. A parallel aim was to create a mounting system that maximized both the visibility of the mummified individual and access to the remains, while offering safe support and long-term stability. In common with all human remains in the Museum’s collection and in compliance with the British Museum’s 2013 policy on Human Remains in the Collection, ethical considerations were also taken into account and the mummified remains were handled, conserved, stored and cared for in an appropriate and respectful manner to ensure their long-term preservation for present and future generations [1, 16–18].

In addition to these research and ethical aims, economy, efficiency, adaptability and reversibility were of importance in developing a subtle and effective mounting system that would be sufficiently adaptable to support a range of fragile mummified tissues and wrappings safely. At the start of the project, considerable time was spent experimenting with support techniques and developing an understanding of the remains on a practical level. Although some individuals were more intact or complete than others and their size, layout, fragility and wrappings differed, a general procedure was developed that accommodated all variations in form and stability.

Figure 10. Cutting a smooth, curved support. Clockwise from top left: the Plastazote strip and sharp knife; bending the Plastazote strip to the required curvature; slicing through the bent Plastazote strip; and the resulting strip with a smooth cut arc, suitable for supporting a bone

Figure 11. Supporting a skull using a padded PTFE ‘doughnut’ and props
The human remains and associated bagged or boxed human tissues were transferred carefully to the conservation studio and placed on a padded surface covered with acid-free tissue. The parts were examined, then laid out and photographed. Loose superficial soil was removed using a variety of techniques specific to the fragility of what lay beneath. Larger volumes of soil were removed using an assortment of spatulas, from metal to individually fashioned spoons made from Melinex® polyester sheet. Finer, dusty soil was gently brushed towards the nozzle of a low-powered, adjustable, HEPA-filtered vacuum cleaner covered with a fine net to act as a filter. When necessary, the nozzle diameter was reduced to allow access to crevices and internal areas by inserting a modified plastic pipette into the end of the nozzle to create a precise, pen-like extension. This allowed material of less than 1–2 mm diameter to be vacuumed off and larger fragments to be delicately picked up for removal or examination. Fine tweezers were also useful in retrieving stones and detached pieces. Concreted soil was removed only where this process did not damage the original surface beneath: the most successful technique was to crush the soil between blunt-ended tweezers and vacuum away the residue.

As it was removed, soil was carefully sieved to isolate significant fragments. Soil samples were also kept from different representative areas above, beside and within the bodies. Loose soil and other material from the area of the gut was sampled and retained for future analysis, as it might provide evidence for diet and disease. Each sample was placed in a labelled polythene zip-lock bag and the original position noted, numbered and mapped on a grid diagram. Potential sources of contamination were also kept for future reference, including samples of the materials used on excavation to lift, and contained extraneous material that required removal, cleaning, sorting and replacing in position where appropriate. Dislocated soft tissue fragments and bones were gently taken out to gain access to internal areas. An effective system was developed to keep the different tissues in their relative positions as found: a photograph was taken of the area from above, a life size print of which was attached to a table adjacent to the body. The print was covered with a clear Melinex sheet and the dislocated bones and other fragments were positioned onto their photographed image. The material that ‘belonged’ was later returned to the cavity and the remainder sampled or bagged.

Once cleaned, each individual was laid out in preparation for transfer to a padded board of appropriate size, Figure 7. Cellite® 220 (aluminium honeycomb panel) was chosen as the baseboard because it is stable, lightweight, of moderate cost and, if no longer required, easily recyclable. Each newly cut board had rough edges that required modification before use by sanding down, wiping clean, padding the corners with thin Plastazote (soft LD33 density), wrapping with cotton tape and finally covering with 3M™ 425 aluminium foil tape.

The ‘mattress’ supports were made by cutting a sheet of Plastazote to the same size as the board and wrapping it with Tyvek® (non-woven polythene sheeting) with the smoother side outwards. The Tyvek was adhered to the board using hot-melt glue from a TEC 305 glue gun. The blend of ethylene vinyl acetate and hydrocarbon resin used in the gun had been tested and proved not to off-gas harmful volatile materials.

Plastazote battens with greater rigidity (LD45 density) were attached at each end below the board. This made handling easier as well as allowing space for custom-made trays housing the associated samples to be inserted below the board. At the outset of the project the trays were made using Correx® (corrugated twin-walled polypropylene) sheet but this was later replaced by Premier Fluted Board EB Flute (three-layered archival quality mount board). Of the two materials, the fluted board was quicker to assemble, more rigid and attracted less dust. Within the trays further subdivisions could be made as necessary by creating Plastazote walls and pads, held in place with hot-melt glue so that any configuration of the remains or group of samples could be accommodated.

When ready, the mummy was transferred to the board a piece or section at a time, working from the centre outwards and holding each part in position using customized Plastazote side and base props or supports, shaped to the curvature of the contact area. Sometimes the mummy was so fragmentary that it was necessary for it to remain on the cotton sheet that had been used to support it on excavation, so this was secured to the mattress by pinning it in position.

The Plastazote supports were secured in position by pinning through to the mattress beneath with long stainless steel ‘Austerlitz’ pins, Figure 8. This method allows reversibility as the pins may easily be withdrawn to remove or reposition the props or to allow access to the mummified remains for research purposes.
Where edges of the Plastazote supports were in contact with vulnerable areas, the surface was smoothed or padded. This was achieved by a variety of methods: sanding with fine sandpaper; cutting with a Hot Knife Thermocutter and immediately rubbing the heated surface to smooth it; covering the support with Relic Wrap® (a thin, malleable, very smooth and stable Telfon® film); or cushioning with pads of soft polyester wadding beneath Relic Wrap, Figure 9. As the project progressed, two simple and rapid Plastazote cutting techniques became standard procedures:

- To cut a smooth curve that was suitable for supporting, for example, a femur, a length of Plastazote was placed on the cutting mat, bent to the desired curve (matching the contour of the femur) and the protruding part sliced off straight with a single stroke of a large, very sharp knife. On release, the Plastazote length sprang back to give a perfectly smooth arc with the same profile as the section that had been sliced off, Figure 10.
- To support particularly fragile tissues with a very soft cushion, a pad or a ‘sausage’ of polyester wadding was wrapped in Relic Wrap, shaped to fit the required area and pinned into position. A doughnut shape was ideal to support a skull, braced with Plastazote buttresses where necessary, Figure 11.

If necessary, strips ties were pinned into the mattress on either side of any unstable area to secure it further. The type of strip varied according to need: polytetrafluoroethylene (PTFE) tape was used for very delicate areas, while Tyvek or thin Plastazote provided greater strength elsewhere. The supports and ties were carefully placed so that they were in contact only with the most stable areas. Finally, the mounts were labelled, the final layout photographed (Figure 12), and treatment reports completed.

Although convenient, strong and lightweight, the use of these aluminum baseboards has the drawback that they can interfere with computerized tomography (CT scanning). Small metal objects – such as the pins used in the mounting stage above or ancient Egyptian amulets placed in the mumified remains by the embalmers – do not significantly affect the X-rays and any residual ‘artefacts’ in the data can be accounted for when generating 3D visualizations, particularly when using dual-energy CT scanners [7]. When one of the mummies was CT scanned in preparation for the Ancient Lives, New Discoveries exhibition [7], it was relatively straightforward to temporarily substitute a wooden board for the Cellite baseboard while keeping the mattress with all its supports in place [18]. For the longer term, non-metal substitutes for both the boards and pins are being researched.

Collaboration and wider benefits of the project

Four placement students (one from the Winterthur/University of Delaware Program in Art Conservation, USA, and others from the MSc courses in both Forensic Archaeological Science and Conservation for Archaeology and Museums at University College London), as well as five British Museum colleagues, assisted for periods varying from a few weeks to six months. Working on materials with which they were not familiar offered a challenging experience, but the project, particularly the development and implementation of the passive conservation process, proved rewarding [19].

Sharing the practices developed in the project and the information gained on the remains was one of the core aims of the project. Personal contacts between the team and colleagues, many of whom came to visit the project, were useful in both exchanging information and disseminating ideas, methods and materials. Substantial outputs included a paper for the ICOM Conservation Committee Leather and Related Materials Working Group meeting in Germany [9], and a chapter on the conservation and care of human remains in the monograph Regarding the dead: human remains in the British Museum [17], while summaries were published in The Clothworker [20], and the Ancient Egypt and Sudan Newsletter [21]. The project was also the subject of a number of presentations.²

Following the end of the project a two-day symposium on the care and conservation of human remains with a focus on natural mummies was held on 20–21 April 2015 and included practical sessions that demonstrated the storage and mounting systems developed during the course of the research. The practical session built on training sessions developed for visiting curators from institutions in Sudan and Egypt.

Conclusions

There are clear benefits beyond the project itself when a specific conservation problem is given the resources to tackle it comprehensively. Each individual mummy has now been systematically cleaned, stabilized, recorded and mounted using passive methods so as not to affect future research potential. The knowledge gained from the project undertaken as part of the Conservation Research Fellowship has been passed on to others via publications, presentations, studentships, studio visits and meetings.

As the individuals treated during this project are part of larger, mostly skeletonized, assemblages, their study will add greatly to the physical anthropological and other data derived from skeletal remains. These rare mummies, from a period when artificial mumification was no longer practised, are revealing aspects of the Medieval period that do not usually survive in the archaeological record, such as tattoos and pathological changes in the soft tissues [7, 16, 20]. It is now possible to start to build a picture of the Medieval period that goes beyond the data derived from skeletal remains and this should provide extraordinary insights into the people and cultures of the middle Nile Valley.

Appendix: The Clothworkers’ Foundation Conservation Research Fellowship

The Clothworkers’ Foundation, through a Conservation Research Fellowship, provided funding to undertake the conservation and mounting of the mumified remains. This fellowship allowed the Senior Fellow (BW) to focus specifically on the project described here, while a Junior Fellow was employed to undertake her day-to-day work, benefiting both parties. The project outcomes included:

- Development and implementation of a strategy for the stabilization of the Fourth Nile Cataract mummies so that they may be stored appropriately and studied;
- Investigation of new storage materials for potential use;
• Devising a considered conservation treatment that stabilizes the mumified remains but does not impact on future scientific analysis;
• Collaboration with researchers from other institutions with analogous collections and conservation challenges;
• Disseminating the results.

Acknowledgements

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Materials and suppliers

• Cellite® 220: TRB Lightweight Structures Ltd, 12 Clifton Road, Huntingdon PE29 7EN, UK. Email: info@trbls.com
• Plastazote: Ramplas Ltd, 84 Birmingham Road, Dudley, West Midlands DY1 4RJ, UK. Email: sales@ramplas.com
• Premier Fitted Board EB Flute: Conservation by Design Ltd, Timecare Works, 5 Singer Way, Bedford MK42 7AW, UK. Email: info@cxdltd.com
• TEC 305 glue gun: Techsil, Unit 34, Bidavon Industrial Estate, Waterloo Road, Bidford on Avon, B50 4JN, UK. Email: sales@techsil.co.uk
• Thermocutter, Relic Wrap™ and Tyvek®: Preservation Equipment Ltd, Vinces Road, Diss, Norfolk IP22 4HQ, UK. Email: info@preservationequipment.com

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References


Notes

1. Gemma Aboe (a Joint Heritage Lottery Fund/Institute of Conservation intern with the British Museum and the Petrie Museum of Egyptian Archaeology) and Siska Genbrugge (a student on a placement from the master’s program in the conservation of archaeological and ethnographic material at UCLA/Getty) assisted with the survey.
2. In addition to a paper presented at the Sudan Archaeological Research Society conference in 2013, presentations were made to groups visiting the project during regular ‘open mornings’, for example from the Wellcome Institute, Museum of London, Natural History Museum, Cambridge University Museums and University College London.
Early Byzantine glass weights: aspects of function, typology and composition

Chris Entwistle and Andrew Meek

SUMMARY This contribution presents a selection from the British Museum’s collection of Byzantine glass weights, which comprises 180 pieces. Four distinct categories from within the overall corpus have been chosen. In certain instances, some of these types can be dated to the specific years of the primary issuing authority, the eparch or prefect of Constantinople or to the reigns of individual emperors; others represent distinct regional types and secondary production centres, perhaps under the control of different provincial officials. They range in date from around ad 500 to the middle of the seventh century. Some 44 of these glass weights were analysed using scanning electron microscopy with energy dispersive X-ray analysis and all were found to have been produced with soda-lime-silica glasses made with a natron flux. The glasses could be associated with previously established compositional types based on minor variations in their chemical composition. ‘Strong’ HIMT, Egypt I and Egypt II glasses were not found, adding evidence to their suggested usage patterns during this period. Two common glass types known to have been in circulation at this time, ‘weak’ HIMT and Levantine I, were both found in the assemblage. Some other glass types that may result from variations in the recipes used for these glass types, or the recycling of glass, were also found. There are, however, few clear links between dating or provenance and compositional type in this assemblage, suggesting that the producers of these weights obtained their supplies of glass from various sources.

Introduction
Towards the end of the fifth century and during the first decades of the sixth century AD, the Early Byzantine Empire in the eastern Mediterranean witnessed a series of widespread fiscal and administrative reforms initiated by the emperor Anastasius (AD 491–518) and continued by Justinian I (AD 527–565). These included, inter alia, a revamping of the copper coinage that saw the introduction of major denominations such as the follis and half follis, and an increase in the number of mints, which subsequently led to a proliferation in the circulation of the gold coinage, exemplified by increased releases of the nomisma and its divisions, the semissis and tremissis [1; p. 4]. Further innovations included the introduction of the five-stamp system on silver vessels, which utilized both imperial and officials’ busts and monograms as a means of validation. It is against this background of monetary reform that the initial introduction of glass as a material for commodity and coinage weights may have taken place. Unlike their Arabic counterparts, issued in vast numbers by successive dynasties from the Umayyads to the Ayyūbids [2], early Byzantine glass weights have not been the subject of systematic study. Indeed many questions relating to their function, origin and date remain unresolved. This contribution, which presents the results of compositional analyses on 44 dated examples in the British Museum’s collection, touches tangentially on some of these issues. Its main focus, however, is an attempt to determine the geographic origin of the four types discussed in detail below: types A and B, which have long been considered to be Constantinopolitan in origin, and types C and D, which are thought either to represent provincial officials, and therefore made outside the capital, or to have been made in Egypt between AD c.642 and 692 [3, 4].
Function

Glass had obvious advantages as a material for weights: it was a relatively inexpensive medium, easy to manufacture, readily detectable if tampered with and, unlike some metal counterparts, not prone to oxidation or corrosion. Byzantine glass weights are remarkably homogenous in appearance as the vast majority take the form of a disk with a central impressed area enclosed by a rolled rim. A number of stages are apparent in their manufacture. A gob of molten glass was probably poured from a ladle onto a flat marble or metal surface. Then an intaglio die bearing the relevant design was pressed into the centre of the hot glass. Downward pressure from the die would cause the gob to flatten outwards forming the rolled rim as an edge. The die employed was probably of metal as occasional iron residues in the form of flakes and scale on the fronts and backs of the weights indicate that the dies (and probably the plates) were of this material [5, 6]. The irregular shapes of the disks illustrate that they were not poured into depressions in the plate prior to stamping. Any examples that proved to be severely over or under weight were probably remelted as cullet and reused.

While it has generally been held that the majority of these glass disks were intended as coin weights, their precise function has occasionally been disputed on the grounds that they do not always correspond exactly with known coin denominations [7; pp. 84–85]. This counter-argument implies that they were originally intended to be highly accurate measures of coins and not, as contemporary coin balances would suggest, simply rule-of-thumb weights for checking the tolerance above or below which a coin would not be accepted. An unpublished statistical analysis of over 500 glass weights suggests that the majority were intended to weigh the gold nomisma/solidus (c.4.55 g), semissis (c.2.27 g) or tremissis (c.1.52 g), the three principal gold coins in circulation during the sixth and seventh centuries AD [8]. This conclusion is further supported by two other statistical studies. A frequency table based on 222 examples from various published sources, as well as unpublished weights in the American Numismatic Society Museum in New York, found three distinct peaks: 37 examples weighing between 4.41 and 4.60 g; 34 examples ranging from 2.01 to 2.20 g; and 19 specimens between 1.40 and 1.60 g [9; p. 78]. A second study, of the 158 examples in the De Menil Collection, Houston, showed three similar peaks: 21 examples between 4.31 and 4.50 g; 18 between 2.11 and 2.30 g; and 17 between 1.31 and 1.50 g [10].

In addition to the statistical evidence, Byzantine glass weights frequently occur in archaeological contexts that leave little doubt as to their function. Only a few can be mentioned here, but among the most important is the grave of an Avar goldsmith discovered at Kunzenmártom in Hungary in 1932 [11; pp. 41–47, plates IV–VI], whose grave goods included equal-arm balances with pans together with nine Byzantine weights, five of copper alloy and four of glass. Similar juxtapositions with weighing equipment can be observed at a number of other sites, including two further excavations in Hungary at the Avar cemeteries of Jutas [12; p. 32, plate VIII] and Pókaszept [13; pp. 423–426, plates 2 and 4]. Comparable groups have been preserved in more obvious commercial contexts. One of a complex of 19 shops [E14] that lined the north side of the road known as the main avenue at Sardis yielded three glass weights all stamped with cruciform monograms: these were found with two square, one nomisma bronze weights and a bronze half nomisma discoid weight. Further finds inside the shop included a copper alloy steelyard with a lead weight and fragments of balance beams and pans [14; p. 86, figs 464–468 and 477–482]. Similar glass weights were also found in Room N of a ‘residential unit’ in Sector MMS/S in a western ‘suburb’ of Sardis [15; pp. 105–118]. This discovery constituted the largest known discovery of
Byzantine weights from a discrete archaeological context. The hoard was composed of 21 greenish-blue glass weights all stamped with the same cruciform monogram. Of great interest is the metrology of this group: of the 21 examples, 12 fall in the range 4.15 to 4.36 g, four between 2.03 and 2.16 g and three between 1.40 and 1.42 g. The remaining two weigh 3.91 and 3.85 g respectively, but both are damaged. Statistically the three major groups again cluster quite convincingly around the weights of the nomisma, semissis and tremissis. Further south, the collapse of the second storey of a workshop preserved a similar assemblage at Tel Naharon in Israel. Finds at this site included four copper alloy scales – three of which were balances and the other a steelyard – and several sets of weights of glass, bronze and haematite. All the coins found in the workshop dated to the sixth century AD [16]. Finally, at the unpublished site of Shiqmona, also in Israel, eight discoid copper alloy weights were excavated, together with three of glass, the latter all issued by the eparch Flavios Gerontios, prefect of Constantinople in AD c.561: Nos 21–22 in the appendix.

**Typology**

Well over 20 different types of Byzantine glass weight have survived, but only four categories are considered here. These have been selected because of the relative ease with which they can be dated, sometimes to the reigns of individual emperors or the terms of office of particular prefects of the capital. In addition, all four types are thought to derive from specific locations within the wide area in southeastern Europe and the eastern Mediterranean throughout which glass weights were distributed, Figure 1.

**Type A: ‘imperial’ weights**

This category is loosely defined by the presence of one or more nimbed imperial busts, sometimes in conjunction with other busts (the prefects of Rome and Constantinople or Christ) or accompanied by inscriptions or monograms, Figure 2. Given the rather worn condition of many of these weights, details of portraiture and costume rarely survive, although in some instances items of jewellery – such as diadems and pendilia – can be discerned. The imperial busts and monograms that appear on type A weights show close parallels with those that appear as stamps on the reverses of sixth and seventh century AD silver vessels and serve a similar function, lending the weights an official character by suggesting governmental validation through the use of the imperial image [17; tables I–III].

**Type B: weights with the bust of an eparch and inscription**

This category is normally represented by weights stamped with the frontal bust of an eparch enclosed by an identifying Greek inscription, Figure 3. The eparch is generally depicted holding a *mappa* – the linen handkerchief thrown to indicate the start of races in the circus games – or a sceptre, or occasionally both. As with the busts employed on weights of type A, details of portraiture and clothing are rarely evident. Various inscriptions are employed on this type of weight: the standard formula is prefixed with the word Επί (in the time of) followed by the eparch’s name and title in the genitive case. Occasionally the title is omitted, but is clearly to be inferred: weights issued by both Flavios Gerontios and Flavios Zimarchos fall into this category: Nos 21–23 in the appendix. Sometimes the honorific ενδοξοτατου (most blessed) is included, with a superscript ‘s’ as a contraction for the last five letters. A final variant, represented by a rare group of weights, employs the phrase PWMHC (Ρωμης; ‘of [New] Rome’, i.e. Constantinople) in columnar form in the field: No. 20 in the appendix.

The names of 22 different eparchs have been recorded on this category of weight. Of these six can reasonably be identified with sixth-century eparchs: Demosthenos in the
late 510s; Theodoros on four occasions in the late 510s or early 520s; Sergios during the latter half of the reign of Justinian; Ioannes either with Ioannes Kokkorobios in AD 550, or another Ioannes thought to have been prefect during the reign of Maurice Tiberios (AD 582–602); Flavios Gerontios between AD 560 and 562; and Flavios Zimarchos on two occasions, the second being in AD 565. A further seven correspond to known prefects of the first half of the seventh century: Damianos under Heraklios before AD 630; Eulampios between approximately AD 612 and 654; Kosmas in AD 609; Leontios in AD 603; Rogatos early in the reign of Heraklios; Theodoros in AD 612; and Theopemptos in AD 605 or 607. The known date range thus spans the reigns between Justin I (AD 521–527) and Heraklios (AD 610–641) [18, 19].

**Type C: weights with a box or cruciform monogram**

By far the most common form of glass weight is that stamped with either a box/block or cruciform monogram, Figure 4. The former is generally composed of a central ‘eta’, ‘mu’, ‘nu’ or ‘pi’, with the letters ‘omicron’ and ‘upsilon’, indicating the genitive case, placed at the apex of the vertical strokes. Other letters could be affixed internally or externally to the vertical, horizontal or diagonal bars. The cruciform monogram, as its name implies, takes the form of a cross, with letters placed at the ends of the arms. Sometimes the arms of the cross emanate from a central ‘theta’, ‘pi’ or ‘phi’. Unlike in the box type monogram, the ‘omicron’ and ‘upsilon’ are generally combined in a Ψ-shaped formation placed at the top of the vertical bar. The earliest Byzantine monograms to be found on weights seemingly date to the third quarter of the fifth century AD, when their emergence was possibly influenced by the slightly earlier appearance of a rather basic form of box type monogram on the bronze nummi of Theodosios II, dating to the early 440s [20; p. 148, pl. 17]. It should be noted, however, that these monograms, which first appear on copper alloy exagia solidi of the eastern emperors Marcian (AD 450–457) and Leo (AD 457–474), differ quite markedly from what might be considered the typical sixth century AD monogram described above in that they employ mainly Latin letters [21; pp. 20–21]. There is a general consensus that the box type was predominant in the period AD c.500–550, with the cruciform type gradually superseding it through the course of the second half of the century.²

Hundreds of different monograms have survived on this type of weight: in some instances they resolve as the same name, a popular example being ‘of Timotheos’ here represented by two different forms (Figure 5), but the vast majority, insofar as it is possible to decipher them with any reliability, seem to resolve as individual names. The accepted chronology for these glass weights is that their use lasted for around 150 years, from the reign of Anastasius to the Persian and Arab invasions of Syria and Egypt in the 630s and 640s AD. Given that it is known from prosopographical evidence that the office of eparch of Constantinople was held by the same person on more than one occasion (e.g. Theodoros Teganistes is known to have held the office at least four times in the late 510s/early 520s [22]), there were probably only around 100 different individuals who were prefects of the capital during these 150 years. As the weights bear hundreds of different individual box or cruciform monograms that resolve as discrete names, these monograms must refer to officials other than simply the prefect of the capital. Although there is a possibility that some weights were issued by officials who were subservient to the prefect of Constantinople – the ninth-century Book of the Eparch refers to a boullotai [23; p. 317], literally ‘inspector of seals’ – it is more likely that they were issued by the prefects of the major cities of the Late Antique world such as Antioch and Alexandria.

**Type D: ‘Arab-Byzantine’ weights**

In 1948, Jungfleisch published an unusual glass weight with no inscription or monogram but decorated with two imperial busts – tentatively identified as Constans and Constantine IV (AD 654–668) – holding a cross between them [3]. Pointing out various iconographic anomalies with other Byzantine ‘imperial’ weights, Jungfleisch suggested that it was an Arabic copy and coined the phrase ‘arabo-byzantine’ to describe it. He further argued that, after the fall of Egypt to the Arabs in AD 640–642, the Byzantine administrative system was so totally disrupted that the issuance of weights by the relevant Byzantine authorities ceased. In the interval between then and the introduction of a series of purely Arabic glass weights by
the reforming caliph Abd’ al Malik in AD 692, someone must have assumed administrative responsibilities for the production of weights. While Byzantine glass weights would have remained in circulation for some time, eventually most would have become unusable through a combination of breakage and wear. Jungfleisch argued that this lacuna was filled by ‘Coptic’ merchants issuing weights on their own authority, but using as their prototypes the old Byzantine series. Balog subsequently developed Jungfleisch’s thesis and proposed three different categories of ‘arabe-byzantine’ weights with: a debased monogram; a denominational mark; or with a bust but no inscription [4].

Of these three categories only the third merits serious consideration. The problem with Balog’s first type is that all the examples of debased monograms cited by him are of the box rather than the cruciform type. It seems unlikely that Coptic merchants would be copying a type of monogram which, if the general consensus on its dating is correct, had been out of widespread use for nearly 50 years. His argument would have been more convincing had the debased monograms been of the cruciform type. At the time of publication Balog knew of only one example of his suggested second category – weights with a denominational mark – although many more examples have been published subsequently that include both commodity and coinage weights. There seems no reason why weights with a mark alone should be classified as ‘arabe-byzantine’ weights as they simply imitate the most common type of Byzantine metal weight.

A more compelling case can perhaps be made for Balog’s third category – those weights stamped with a bust only. His examples are almost totally lacking in facial features or details of costume and insignia, very often representing a mere approximation of the human form. Balog does not discuss whether these weights were imitating imperial or eparchal busts, but it is clear from a number of examples in the British Museum’s collection that they were probably copying both. Examples of the former include two weights whose busts bear crude radiate crowns and pendilia, Figure 6. There are no identifying inscriptions, but the busts are flanked by two crosses.

The latter type is represented by two very unusual weights, both with a frontal bust holding up an object in either hand, presumably a mappa and a sceptre (Figure 7: Nos 41–42 in the appendix). Enclosing the bust is an inscription that is, unfortunately, very blurred but which might be in Greek, although there are hints that the letters are Cufic. If correct, this would be the clearest evidence for ‘arabe-byzantine’ glass weights.

### Composition

#### Introduction

In recent years a large number of first millennium AD glass assemblages has been analysed compositionally and published, and compositional types have been defined based on various characteristics associated with the raw materials used to make the glass [24]. The major component of these glasses, and that most commonly used to differentiate between types, is sand, with impurities in the silica-rich sand sources giving rise to the majority of the compositional differences seen in Table 1.

Some of the types have chronological or geographical limits that can be used to draw conclusions about the glass objects analysed. The glass weights analysed in this study date to the sixth and seventh centuries AD, with production attributed to Constantinople, the eastern Mediterranean and Egypt. The most significant natron-based glass types in circulation during this period, and at these locations, are termed Levantine I, Levantine II, HIMT (with high manganese, iron

### Table 1. Selected previously published compositional types of natron-based glass from the first millennium AD

<table>
<thead>
<tr>
<th>Type</th>
<th>Site</th>
<th>Na₂O</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>K₂O</th>
<th>CaO</th>
<th>TiO₂</th>
<th>MnO</th>
<th>FeO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levantine I</td>
<td>Apollonia</td>
<td>15.2</td>
<td>0.63</td>
<td>3.05</td>
<td>70.6</td>
<td>0.71</td>
<td>8.07</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.35</td>
</tr>
<tr>
<td>Levantine II</td>
<td>Bet El’ezr</td>
<td>12.1</td>
<td>0.63</td>
<td>3.32</td>
<td>74.9</td>
<td>0.46</td>
<td>7.16</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.52</td>
</tr>
<tr>
<td>Egypt I</td>
<td>Wadi Natrun</td>
<td>21.4</td>
<td>0.90</td>
<td>2.70</td>
<td>66.5</td>
<td>0.34</td>
<td>3.70</td>
<td>0.27</td>
<td>&lt;0.1</td>
<td>1.00</td>
</tr>
<tr>
<td>Egypt II</td>
<td>Ashmunine</td>
<td>15.0</td>
<td>0.50</td>
<td>2.10</td>
<td>68.2</td>
<td>0.20</td>
<td>10.8</td>
<td>0.28</td>
<td>0.20</td>
<td>0.70</td>
</tr>
<tr>
<td>HIMT</td>
<td>Carthage</td>
<td>18.7</td>
<td>1.29</td>
<td>3.18</td>
<td>64.8</td>
<td>0.44</td>
<td>5.24</td>
<td>0.68</td>
<td>2.66</td>
<td>2.07</td>
</tr>
<tr>
<td>Weak HIMT</td>
<td>Bubastis</td>
<td>17.9</td>
<td>0.93</td>
<td>2.32</td>
<td>66.1</td>
<td>0.54</td>
<td>7.12</td>
<td>0.15</td>
<td>1.05</td>
<td>0.83</td>
</tr>
<tr>
<td>HIT</td>
<td>Dichin</td>
<td>17.5</td>
<td>1.09</td>
<td>3.16</td>
<td>68.0</td>
<td>0.38</td>
<td>5.17</td>
<td>0.67</td>
<td>0.05</td>
<td>1.42</td>
</tr>
</tbody>
</table>

Note: Based on data from [25–27, 29, 30, 32].
Table 2. Accuracy and standard deviation measurements (wt%) for the Corning glass standard A

<table>
<thead>
<tr>
<th>Comming A</th>
<th>Na₂O</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>P₂O₅</th>
<th>SO₃</th>
<th>Cl</th>
<th>K₂O</th>
<th>CaO</th>
<th>TiO₂</th>
<th>MnO</th>
<th>FeO</th>
<th>CoO</th>
<th>NiO</th>
<th>CuO</th>
<th>ZnO</th>
<th>Sb₂O₃</th>
<th>PbO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krowned</td>
<td>14.32</td>
<td>2.81</td>
<td>1.01</td>
<td>66.56</td>
<td>0.14</td>
<td>0.16</td>
<td>0.10</td>
<td>18.9</td>
<td>2.63</td>
<td>2.53</td>
<td>0.98</td>
<td>1.04</td>
<td>1.04</td>
<td>1.04</td>
<td>0.98</td>
<td>11.8</td>
<td>1.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Measured (n = 14)</td>
<td>14.78</td>
<td>2.63</td>
<td>0.83</td>
<td>66.85</td>
<td>0.08</td>
<td>0.24</td>
<td>0.15</td>
<td>2.97</td>
<td>5.05</td>
<td>0.98</td>
<td>1.04</td>
<td>1.04</td>
<td>1.04</td>
<td>1.04</td>
<td>1.04</td>
<td>1.18</td>
<td>1.69</td>
<td>0.08</td>
</tr>
<tr>
<td>Accuracy</td>
<td>1.8</td>
<td>6.8</td>
<td>21.7</td>
<td>4</td>
<td>75.0</td>
<td>33.3</td>
<td>33.3</td>
<td>1.4</td>
<td>18.4</td>
<td>1.12</td>
<td>11.8</td>
<td>11.8</td>
<td>1.12</td>
<td>11.8</td>
<td>11.8</td>
<td>11.0</td>
<td>11.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.08</td>
<td>0.03</td>
<td>0.01</td>
<td>0.15</td>
<td>0.03</td>
<td>0.05</td>
<td>0.01</td>
<td>0.03</td>
<td>0.04</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Table 3. Normalized VP-SEM-EDX results for the glass weights

| No. in appendix | Production place | Colour | Date | Type | Na₂O | MgO | Al₂O₃ | SiO₂ | P₂O₅ | SO₃ | Cl | K₂O | CaO | TiO₂ | MnO | FeO | CoO | NiO | CuO | ZnO | Sb₂O₃ | PbO |
|-----------------|-----------------|--------|------|------|------|-----|-------|------|------|-----|----|-----|-----|------|-----|-----|-----|-----|-----|------|------|
| 1. 1980,061.12 | Constantinople (?) | Green | 582–602 | A | 19.6 | 1.2 | 2.9 | 64.3 | 0.2 | 0.5 | 0.8 | 1.0 | 7.5 | 5.2 | 0.4 | 1.9 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 2. 1990,060 | Constantinople (?) | Olive green | 582–602 | A | 19.6 | 1.3 | 3.2 | 63.8 | 0.2 | 1.0 | 0.5 | 1.0 | 6.5 | 0.2 | 0.8 | 1.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 3. 1920,104 | Constantinople (?) | Green | 540–565 | A | 19.3 | 1.2 | 2.4 | 65.7 | 0.1 | 0.5 | 0.9 | 0.6 | 6.8 | 0.1 | 1.3 | 0.9 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |
| 4. 1997,0218 | Constantinople (?) | Pale brown | 540–565 | A | 20.4 | 1.1 | 2.3 | 64.7 | 0.1 | 0.7 | 1.0 | 0.8 | 6.7 | 0.1 | 1.3 | 0.9 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |
| 5. 1986,0406 | Constantinople (?) | Brown | 540–565 | A | 21.7 | 1.0 | 2.2 | 63.1 | 0.1 | 0.4 | 1.0 | 0.5 | 7.0 | 0.1 | 1.5 | 1.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |
| 6. 1997,0218 | Constantinople (?) | Blue | 550–600 | A | 18.2 | 1.0 | 2.4 | 64.9 | 0.1 | 0.4 | 0.9 | 0.6 | 6.6 | 0.1 | 1.2 | 0.9 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |
| 7. 1980,061.16 | Constantinople (?) | Blue | 550–600 | A | 19.2 | 0.9 | 2.4 | 64.1 | 0.1 | 0.4 | 0.8 | 0.6 | 6.6 | 0.1 | 1.3 | 1.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |
| 8. 1987,0703 | Constantinople (?) | Blue | 510 s | B | 18.6 | 1.2 | 2.2 | 66.9 | 0.1 | 0.4 | 0.9 | 0.7 | 7.0 | 0.2 | 1.2 | 1.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |
| 9. 1980,061.17 | Constantinople (?) | Green | 522–523 | B | 16.9 | 0.9 | 2.7 | 68.4 | 0.1 | 0.5 | 0.9 | 0.7 | 5.2 | 0.2 | 1.1 | 2.3 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |
| 10. 1986,0406 | Constantinople (?) | Green | 522–523 | B | 17.6 | 1.5 | 2.8 | 63.0 | 0.2 | 0.5 | 0.9 | 1.2 | 7.9 | 0.2 | 1.3 | 2.8 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |

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Table 4. Average VP-SEM-EDX data for each of the compositional types found

<table>
<thead>
<tr>
<th>Type</th>
<th>n</th>
<th>Na₂O</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>K₂O</th>
<th>CaO</th>
<th>TiO₂</th>
<th>MnO</th>
<th>FeO</th>
</tr>
</thead>
<tbody>
<tr>
<td>wHIMT (high Fe)</td>
<td>8</td>
<td>18.74</td>
<td>1.20</td>
<td>2.78</td>
<td>64.36</td>
<td>0.83</td>
<td>6.93</td>
<td>0.16</td>
<td>1.04</td>
<td>2.20</td>
</tr>
<tr>
<td>wHIMT (low Mn)</td>
<td>17</td>
<td>19.01</td>
<td>1.09</td>
<td>2.53</td>
<td>65.15</td>
<td>0.78</td>
<td>7.01</td>
<td>0.15</td>
<td>1.28</td>
<td>0.92</td>
</tr>
<tr>
<td>Levantine I / wHIMT</td>
<td>7</td>
<td>19.18</td>
<td>1.12</td>
<td>2.50</td>
<td>65.97</td>
<td>0.81</td>
<td>7.38</td>
<td>0.15</td>
<td>0.36</td>
<td>0.91</td>
</tr>
<tr>
<td>Levantine I</td>
<td>4</td>
<td>17.17</td>
<td>0.83</td>
<td>3.25</td>
<td>65.99</td>
<td>0.87</td>
<td>8.74</td>
<td>0.10</td>
<td>0.38</td>
<td>0.78</td>
</tr>
<tr>
<td>'Decoloured'</td>
<td>6</td>
<td>15.39</td>
<td>0.70</td>
<td>3.17</td>
<td>69.58</td>
<td>0.64</td>
<td>8.75</td>
<td>0.09</td>
<td>0.03</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Note. The values are reported as percentages of oxides and are averages from analyses on more than one area: n = the number of areas analysed. Sb₂O₃ and NO were not found above the detection limits for this methodology in any of the objects analysed.
Figure 8. Plot of wt% calcium oxide against wt% aluminium oxide

Figure 9. Plot of wt% iron oxide against wt% aluminium oxide

Figure 10. Plot of wt% iron oxide against wt% manganese oxide
and titanium), Egypt I and Egypt II, Table 1 [25–32]. The first two of these groups are associated with production in the Levant and the final two in Egypt, while HIMT is thought to have been produced in northern Egypt, although the precise production location has not been ascertained. While the Egyptian and Levantine types have been well established for some time, the group of HIMT types has remained a subject of debate since their definition in the 1990s [33; p. 290, 34]. There are a number of different subtypes under the umbrella term HIMT. A ‘weak’ HIMT type (hereafter termed wHIMT) and the similar HIMT 2 type [31], contain significant but lower levels of iron, manganese and titanium [29, 31, 35] as well as other elements. Another type, without elevated manganese levels, is known as HIT [30]. As more studies are published, a clearer picture of this family of glass types will hopefully be revealed.

Previous analysis of 38 Byzantine glass pendants from the British Museum’s collection by Rohrs et al. concluded that they were produced from a variety of glass compositions, including Levantine I, HIMT and coloured glass of Roman composition [36]. It was not possible to link these compositions to discrete production sites and instead it seemed likely that those producing these objects obtained their glass from various primary production locations, either directly or via the recycling of glass objects. This study aims to continue that work and to improve understanding of the production of Byzantine glass objects.

Analytical method

Variable pressure scanning electron microscopy with energy dispersive X-ray spectrometry (VP-SEM-EDX) analysis was carried out on the reverse side of the weights. A Hitachi S3700N equipped with an Oxford instruments INCA x-act detector was used. A chamber pressure of 40 Pa was employed so that charge was conducted away from the sample. All the measurements were carried out at a working distance of 10.0 mm, a voltage of 20 kV, a count time of 180 seconds and count rates of 12,000 counts per second. This analytical method resulted in detection limits for most metal oxides of 0.1 weight percent (wt%).

The weights were not sampled as they fitted easily into the sample chamber of the SEM and no coating was needed for analysis at a pressure of 40 Pa. A small area on each object was polished with 6 μm diamond paste to remove the weathered surface of the glass as this crust would influence the analytical results; for full details see [36; p. 180].

Corning glass standard A was analysed to check for accuracy and precision, Table 2. The percentage accuracies of the results for phosphorus pentoxide (P2O5), sulphur trioxide (SO3) and chlorine (Cl) are sufficiently high that data for these components must be considered semi-quantitative.

Analytical results and discussion

Compositional types

All the weights were produced from soda-lime-silica glass and exhibit low magnesium and potassium contents typical of glass produced using a sodium-rich mineral known as natron, Table 3. However, the potassium levels in many of the weights in this assemblage are higher than the majority of similar glasses published elsewhere (compare Table 1 and Table 4). As the weights are believed to have been formed by remelting previously produced glass in an open flame, this may be the result of contamination by fuel ash during this process: see the section on ‘function’ above, and [37] for illustrations of objects produced in a similar manner. An alternative explanation for these differences in the potassium levels found in Levantine glasses, suggested by Tal et al. [38; p. 92], is that the potassium released from wood ash during primary glass production may contaminate the glass melt, resulting in variations in the potassium levels in the glass, even within a single batch.

The glasses analysed in this study can be divided into six compositional types, Table 4. The data were assigned to these types by comparison with previously published data and by using scatter plots to map the data, Figures 8–10. The types are based on the pre-established categories discussed above and are related to the raw materials used to produce the glasses, Table 1. However, some new sub-types were created to explain differences between the data in this study and the pre-established groups.

Six of the glasses in the assemblage were found to have been produced from Levantine I glass, Table 4. This glass type was also found in the Byzantine pendants analysed previously and its chronological and geographical range, discussed above, made it very likely to be found in the glass weights [36, p. 180].

The largest compositional type represented in this assemblage is wHIMT. This group coincides with Rosenow and Rehren’s ‘weak’ HIMT type [29], and shares some similarities with Foster and Jackson’s HIMT 2 type [31]. The glass in one of the type B weights (1987.0703.18) is exceptional, with very high aluminium and fairly high potassium levels, although the compositional data for other elements in this glass still suggest that it is of the wHIMT type, Figures 8–10 and Table 3. The most likely explanation for this object’s compositional differences is contamination from the ceramic crucible in which it was remelted.

There are three further types that share characteristics with wHIMT type glass:

1. wHIMT (high iron) glasses are similar in composition to wHIMT glasses, but have higher iron levels, similar to those of HIMT glass (Figures 9 and 10). This may result from the addition of iron to a wHIMT glass or its production from a sand source different to that used in either the wHIMT or HIMT type glasses.
2. wHIMT (low manganese) glasses also share almost all of the chemical characteristics of wHIMT glasses, but have lower manganese levels, Figure 10. The manganese levels are not as low as those found in HIT glasses, so they represent an intermediate composition between wHIMT and HIT [30]. It has been suggested by Rehren and Cholakova that manganese was an optional addition to the family of HIMT glasses [30]. It may be the case, therefore, that these low manganese wHIMT glasses are the result of the addition of less manganese to the glass batch than was used for the wHIMT or HIMT glasses.
3. Levantine I wHIMT glasses have similar calcium and aluminium levels to Levantine I glass, with iron and manganese levels comparable to the wHIMT low-manganese glasses, Figure 8. This may be the result of mixing glasses.
of these two compositional types or the addition of a raw material rich in manganese and iron to a Levantine I glass. The calcium and aluminium contents and the colours of these glasses correspond more closely to Levantine I glasses than wHIMT, suggesting that the second of these two options is perhaps more likely.

The single object in the ‘decoloured’ compositional group is a purple glass weight from the eastern Mediterranean (1987,0703.4). Even though this glass is purple in appearance, it is of a compositional type associated with glasses decoloured with manganese (see [31] and [39], type 2a). It has low levels of iron, which discriminates it from all types of HIMT glass, and low calcium and aluminium, which differentiates it from Levantine I glass. This glass may have been produced by the addition of further manganese to an already manganese-decoloured glass.

The final glass weight to be discussed is 1980,0611.60, the busts on which suggest that it dates to the early seventh century AD. However, its composition has characteristics that are not associated with Byzantine glasses and indicate a modern production: low chlorine (0.1% Cl), high barium (c.1 wt% BaO from semi-quantitative analysis not reported in Table 3) and zinc (1.4% ZnO: Table 3). It is therefore assumed that the glass used to produce this weight is not ancient.

**Colours**

Green, blue-green, aqua and brown colours in glasses of the types discussed in this study are normally associated with the presence of iron and copper, Figure 11. Various shades can be produced using these two metals by altering the furnace temperature and adjusting the environment to make it more or less reducing or oxidizing. In the samples analysed here, copper is only present at levels above 0.1 wt% CuO in glasses that are coloured a strong blue by the addition of cobalt. The four colours seen in this assemblage are, therefore, principally the result of the presence of iron in the glasses. This contrasts with the pendants analysed previously, where copper was present at a level above 1 wt% CuO (and not associated with significant cobalt levels) in six of the 38 pendants analysed [36; p. 180].

The majority of green or green-brown weights were produced from wHIMT glasses (Table 5); previous studies have established that shades of green and brown are associated with glasses of the HIMT compositional family [31; p. 189, 36; p. 183]. As some green weights were also found in the Levantine I group, these colours are not exclusively associated with wHIMT glasses. Five of the six aqua or blue-green weights were produced from Levantine I or Levantine I/ wHIMT glasses; the majority of Levantine I glasses analysed previously were of a blue-green colour [31; p. 190]. The single blue-green weight produced from wHIMT (low Mn) glass – 1983,1108.1 – is significantly darker in colour than the other five.

The blue weights were all produced from wHIMT glasses (Table 5); 12 of the 13 were coloured with cobalt and are a very dark blue, so dark as to appear almost opaque black. All but one (1884,0509.13) also contain significant levels of lead (0.2–2.2 wt% PbO). The presence of lead and antimony in translucent cobalt blue glasses of the post-Roman period is normally attributed to the use of lead-antimonite-opacified cobalt-containing blue glasses as a raw material [32, 40, 41]. In the case of the blue weights, antimony was not, however, detected at a significant level and previous studies have suggested that the presence of lead may be associated with the particular cobalt-rich raw material used to colour the glass [42; pp. 240–242], which seems likely also to be the case in these glass weights.

One glass weight (1882,0510.20) is a more translucent blue and does not contain cobalt or copper at a detectable level. The blue colouration may be due to the presence of very low levels of cobalt, below the detection levels of the analytical technique employed, but a contribution is likely to be made by iron, which can produce a blue colour if the glass is remelted in a particular environment. The difference in colouration between this object and others with fairly similar
compositions is most likely to be the result of remelting in a reducing environment [43; p. 23].

The single red-brown/black weight (1990,0601.17) appears to be a mixture of two different glasses, although its composition is not significantly different from many of the other glasses analysed in this study. Previously, Freestone et al. analysed a black glass mosaic tessera that contained streaks of red and found that the colouration was caused by the precipitation of copper sulphide in the black areas and metallic copper in the red streaks [44; p. 274]. They suggested that variations in melting conditions were able to cause this colouration and it seems likely that this is also the case for the streaked glass analysed here [44].

There are two weights that exhibit characteristics associated with ‘decoloured’ glasses. First, the purple weight (1987,0703.4), which is discussed in detail above, and second, a pale coloured glass weight (1981,0601.3) produced from wHIMT glass. The most likely explanation for the lack of colour is decolouration of the glass by the addition of manganese. As discussed above in relation to the purple weight, manganese can act as a decolourant by counteracting the green/brown colouration caused by iron oxide in the glass. As this weight is not compositionally distinct from the other wHIMT glasses it seems likely that this is also the case for the streaked glass analysed here [44].

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**Regional and workshop groups**

The weights analysed in this study are from three production locations: Constantinople (‘imperial’ weights and weights with the bust of an eparch and inscription: types A and B), the eastern Mediterranean (weights with a box or cruciform monogram: type C) and Egypt (‘Arab-Byzantine’: type D), Table 6. The glass types used in these locations are not distinct from each other, but some patterns can be observed. First, the majority of weights attributed to Constantinople (types A and B) are produced from wHIMT glass (24 of 28). The same can also be said of weights attributed to Egypt (type D: Table 6). The two most likely explanations for this are that the producers in these areas were preferentially using wHIMT glass, or that at the time of production this was the main glass type available to them.

The weights from the eastern Mediterranean (type C) show examples of each compositional type. The small number of eastern Mediterranean weights analysed in this assemblage does not allow any definite conclusions to be drawn about the relative popularity of the different glass types, although it seems that the producers used glasses that originated from a variety of primary sources.

Four of the type A weights from Constantinople were produced using the same die (1997,0218.4; 1980,0611.30; 1893,0409.2; and 1990,0601.17), suggesting that they were made in a single workshop. Weight 1997,0218.4 is produced from red-brown/black glass and the other three from blue wHIMT glass. The compositions of these three blue glasses are so similar that they may have been produced from a single glass source, Table 3. The only significant differences are in their lead and cobalt levels, suggesting that these components may have been added separately to each of the glasses. The red-brown/black weight is produced from wHIMT (high iron) glass. The use of two different glass types in these four objects shows that the single workshop producing them used more than one glass type glass to make weights.

**Chronological patterns**

The weights in this study date to the sixth and seventh centuries AD, Tables 3 and 7. There was no correlation between date and glass type, with every compositional type except ‘decoloured’ found in each century; the only ‘decoloured’ glass dated to the sixth century AD. This lack of correlation limits the extent to which chronological patterns can be established in the glasses that were analysed. However, because the weights are securely dated...
dated, determining their compositional types provides useful information for future studies. Of particular importance is the discovery that the wHIMT glass type was still in use, in Egypt at least, in the mid-to-late seventh century AD, for example in the type D weights 1980,0611.52 and 1986,0406.14.

Some more interesting patterns present themselves when what is absent from this assemblage is considered. First, there are no glasses of the ‘strong’ HIMT type (HIMT 1), a compositional type that was in circulation in the late fourth to the sixth century AD [29, 31]. Although the majority of the weights in the current study date to the sixth century AD, none is of this glass type, which contrasts with the pattern found for the Byzantine pendants in the British Museum collection, where 10 of the 37 objects analysed were found to have been produced from HIMT glass [36, p. 186]. Those pendants dated from the fourth and early fifth century AD, so it is interesting to note that the compositional differences can potentially be linked to a chronological change in the production of two similar object types.

Second, there are no glasses of the Egypt I or Egypt II compositional types. This is also an important finding as Egypt I type glass has a likely start date in the late seventh century AD and an end date in the eighth century AD, while Egypt II is associated with the eighth to the ninth century AD. The well-dated glass weights analysed here (sixth to late seventh century AD) were, therefore, very unlikely to have been produced from Egypt II type glasses, but it is interesting to note that the compositional differences associated with the eighth to the ninth century AD, but not earlier.

Conclusions

This study set out to examine various groups of Byzantine glass weights in an attempt to establish their individual compositional signatures. A number of tentative conclusions may be drawn from these analyses. Weights of types A and B, by virtue of their iconography, have long been assumed to have been made in the capital, Constantinople. There was a slight possibility, therefore, that these weights might have exhibited different compositional characteristics to the main groups already established for the eastern Mediterranean in Late Antiquity, namely Levantine I, Levantine II and HIMT type glasses. That this is not the case is hardly surprising. Clearly the capital either imported glass from these southern production centres or exploited recycled glass from these sources. It is surely no coincidence that the prosopographical evidence for the dating of these weights ceases at much the same time that the glass-producing provinces of Syria/Palestine and Egypt were lost to the Arabs, by the middle of the seventh century AD. That analyses of type C weights – considered to have been made throughout the eastern Mediterranean in the major provincial centres – show a greater compositional range is perhaps also to be expected, given a need to exploit a wider range of sources for the glass. Finally, the inconclusive evidence for weights of type D, which appear to belong entirely to wHIMT, seems to suggest their manufacture in northern Egypt, which would fit well with the theory that this type represents a transitional series produced in Egypt in the period AD 642–692.

Further analyses of the remaining 136 glass weights in the British Museum’s collection would be needed to take this research further, and it would be particularly interesting to see if any of the remaining 18 weights of type D show compositional characteristics associated with Egypt I type glasses.

Appendix: dated examples of Byzantine glass weights

Type A: weights with imperial busts

1. 1920,1104.1. Nimbed and diademed bust of Justinian I (AD 527–565) enclosed by a Latin inscription: DN IVSTINIANVS PP AVG. Diameter (O) 25 mm; mass 4.17 g (nomisma).
2. 1997,0218.1. Nimbed and diademed bust of Justinian I above a retrograde cruciform monogram resolving as ‘of Sergios’ enclosed by a Latin inscription: DN IVSTINIANVS PP AVG. Ø 27 mm; mass 4.46 g (nomisma).
3. 1986,0406.18. As No. 2. Ø 25 mm; mass 4.24 g (nomisma).
4. 1980,0611.2. Nimbed and diademed imperial bust above a box monogram resolving as ‘of Martinos’; dated by bust type to the reign of Maurice Tiberios (AD 582–602). Ø 27 mm; mass 4.21 g (nomisma).
5. 1990,0601.16. As No. 4. Ø 18.5 mm; mass 1.35 g (tremissis).
6. 1980,0611.60. Standing figures of the emperor Phocas (AD 602–610) and his wife Leontia, both crowned and wearing imperial costume. Ø 30.5 mm; mass 3.48 g. The unparalleled composition of the glass of this weight strongly suggests that this is a modern concoction, a glass disk having been impressed with a genuine follis of Phocas.
7–10. 1997,0218.4; 1980,0611.30; 1893,0409.2; and 1990, 0601.17. Stamped with a nimbed and diademed imperial bust above a cruciform monogram resolving as ‘of Euthalios’ flanked by two smaller busts; all four weights from the same die. Ø 24.5, 24, 20 and 21 mm; masses 4.59 g (nomisma), 3.81 g (nomisma?), 2.01 g (semissis) and 2.21 g (semissis).

Type B: weights with a bust of the prefect of Constantinople

11. 1884,0509.13. Bust of an eparch enclosed by a Greek inscription resolving as ‘of Demosthenos’; dated to his prefectship in the late 510s. Ø 23.5 mm; mass 4.03 g (nomisma).
12. 1987,0703.20. As No. 11. Ø 25 mm; mass 3.95 g (nomisma?).

Table 7. Chronology of glass types found in this study

<table>
<thead>
<tr>
<th>Glass type</th>
<th>Date range</th>
</tr>
</thead>
<tbody>
<tr>
<td>wHIMT (high Fe)</td>
<td>Sixth to late seventh century AD</td>
</tr>
<tr>
<td>wHIMT</td>
<td>Sixth to late seventh century AD</td>
</tr>
<tr>
<td>wHIMT (low Mn)</td>
<td>First quarter of sixth to mid-seventh century AD</td>
</tr>
<tr>
<td>Levantine I / HIMT</td>
<td>Sixth to late seventh century AD</td>
</tr>
<tr>
<td>Levantine I</td>
<td>Mid-sixth to mid-seventh century AD</td>
</tr>
<tr>
<td>‘Decoloured’</td>
<td>Sixth century AD</td>
</tr>
</tbody>
</table>

Table 8. Some dated examples of Byzantine glass weights

Type A: weights with imperial busts

<table>
<thead>
<tr>
<th>Weight</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920,1104.1</td>
<td></td>
<td>Nimbed and diademed bust of Justinian I (AD 527–565) enclosed by a Latin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inscription: DN IVSTINIANVS PP AVG. Diameter (O) 25 mm; mass 4.17 g (nomisma).</td>
</tr>
<tr>
<td>1997,0218.1</td>
<td></td>
<td>Nimbed and diademed bust of Justinian I above a retrograde cruciform monogram</td>
</tr>
<tr>
<td></td>
<td></td>
<td>resolving as ‘of Sergios’ enclosed by a Latin inscription: DN IVSTINIANVS PP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AVG. Ø 27 mm; mass 4.46 g (nomisma).</td>
</tr>
<tr>
<td>1986,0406.18</td>
<td></td>
<td>As No. 2. Ø 25 mm; mass 4.24 g (nomisma).</td>
</tr>
<tr>
<td>1980,0611.2</td>
<td></td>
<td>Nimbed and diademed imperial bust above a box monogram resolving as ‘of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Martinos’; dated by bust type to the reign of Maurice Tiberios (AD 582–602).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ø 27 mm; mass 4.21 g (nomisma).</td>
</tr>
<tr>
<td>1990,0601.16</td>
<td></td>
<td>As No. 4. Ø 18.5 mm; mass 1.35 g (tremissis).</td>
</tr>
<tr>
<td>1980,0611.60</td>
<td></td>
<td>Standing figures of the emperor Phocas (AD 602–610) and his wife Leontia,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>both crowned and wearing imperial costume. Ø 30.5 mm; mass 3.48 g.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The unparalleled composition of the glass of this weight strongly suggests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>that this is a modern concoction, a glass disk having been impressed with a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>genuine follis of Phocas.</td>
</tr>
<tr>
<td>7–10</td>
<td></td>
<td>1997,0218.4; 1980,0611.30; 1893,0409.2; and 1990,0601.17. Stamped with a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nimbed and diademed imperial bust above a cruciform monogram resolving as ‘</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of Euthalios’ flanked by two smaller busts; all four weights from the same</td>
</tr>
<tr>
<td></td>
<td></td>
<td>die. Ø 24.5, 24, 20 and 21 mm; masses 4.59 g (nomisma), 3.81 g (nomisma?),</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.01 g (semissis) and 2.21 g (semissis).</td>
</tr>
</tbody>
</table>

Type B: weights with a bust of the prefect of Constantinople

11. 1884,0509.13. Bust of an eparch enclosed by a Greek inscription resolving as ‘of Demosthenos’; dated to his prefectship in the late 510s. Ø 23.5 mm; mass 4.03 g (nomisma).
12. 1987,0703.20. As No. 11. Ø 25 mm; mass 3.95 g (nomisma?)

12 | Chris Entwistle and Andrew Meek
13. 1980,0611.48. Bust of an eparch enclosed by a Greek inscription resolving as ‘in the time of the eparch Theodotos’; dated to the prefectship of Theodotos Kolokynthios in AD 522–523. Ø 22 mm; mass 2.22 g (semissis).

14. 1986,0406.12. As No. 13. Ø 20.5 mm; mass 1.98 g (semissis).

15. 1891,0512.11. As No. 13. Ø 19.5 mm; mass 1.17 g (tremissis).

16. 1986,0406.15. Bust of an eparch enclosed by a Greek inscription resolving as ‘in the time of the eparch Theodoros’; dated to the prefectship of Theodoros in either AD 518–526 or 612. Ø 17.5 mm; mass 1.19 g (tremissis).

17. 1997,0218.2. As No. 16, but the inscription reading ‘of Theodotos’. Ø 19 mm; mass 4.48 g (nomisma).

18. 1892,0613.61. Bust of an eparch enclosed by a Greek inscription resolving as ‘in the time of the eparch Ioannes’; dated to his prefectship between AD 560–562. Ø 25 mm; mass 4.27 g (nomisma).

19. 1892,0613.59. Bust of an eparch enclosed by a Greek inscription resolving as ‘in the time of Flavios Gerontios’; dated to his prefectship in AD 560–562. Ø 25 mm; mass 4.27 g (nomisma).

20. 1884,0509.14. As No. 18, but with the inscription reading ‘in the time of Symeonos, eparch of [New] Rome’. Ø 17 mm; mass 1.45 g (tremissis).

21. 1987,0703.17. As No. 16, but the inscription reading ‘of the eparch Ioannes’. Ø 20.5 mm; mass 2.11 g (semissis).

22. 1987,0703.18. Bust of an eparch enclosed by a Greek inscription resolving as ‘in the time of the eparch Konstantinos’. Ø 19 mm; mass 1.82 g (semissis).

23. 1879,0522.49. Bust of an eparch enclosed by a Greek inscription resolving as ‘in the time of the eparch Rogatos’; dated to his prefectship in AD c.610–612. Ø 25 mm; mass 4.41 g (nomisma).

24. S.322. Bust of an eparch enclosed by a Greek inscription resolving as ‘of the eparch Mousilios’; dated to his prefectship in AD 565. Ø 19 mm; mass 1.64 g (tremissis).

25. 1987,0703.17. As No. 24. Ø 17.5 mm; mass 1.35 g (tremissis).

26. 1879,0522.49. Bust of an eparch enclosed by a Greek inscription resolving as ‘in the time of the eparch Konstantinos’. Ø 20 mm; mass 1.82 g (nomisma).

27. 1980,0611.90. Bust of an eparch enclosed by a Greek inscription resolving as ‘of the eparch Mousilios’; dated to his prefectship in AD c.600–650. Ø 26 mm; mass 3.56 g (nomisma).

28. 1983,1108.1. Bust of an eparch enclosed by a Greek inscription resolving as ‘of the most blessed Domianus’; dated to his prefectship in AD 610–630. Ø 25 mm; mass 4.41 g (nomisma).

29. 1882,0510.20. As No. 28. Ø 25 mm; mass 4.41 g (nomisma).

Type C: weights with a box or cruciform monogram

30. 1987,0703.4. Box monogram resolving as ‘of Thomas’. Ø 23 mm; mass 3.78 g (nomisma).

31. 1980,0611.4. Box monogram resolving as ‘of Paulos’. Ø 26 mm; mass 4.35 g (nomisma).

32. 1990,0601.12. Box monogram resolving as ‘of Konstantinos’. Ø 18 mm; mass 1.75 g (semissis).

33. 1987,0703.3. Box monogram resolving as ‘of Patrikios’. Ø 20.5 mm; mass 2.11 g (semissis).

34. 1980,0611.13. Box monogram resolving as ‘of Methodios’. Ø 20 mm; mass 2.08 g (semissis).

35. 1981,0601.3. Box monogram resolving as ‘of Kyrillos’. Ø 16 mm; mass 0.93 g (tremissis).

36. 1984,0109.1. Cruciform monogram resolving as ‘of the eparch Aristomatchos’. Ø 27 mm; mass 4.48 g (nomisma).

37. 1891,0512.13. Cruciform monogram resolving as ‘of Akakios’. Ø 25 mm; mass 4.46 g (nomisma).

38. 1987,0703.16. Cruciform monogram resolving as ‘of Prokopios’. Ø 20 mm; mass 2.00 g (semissis).

39. 1980,0611.27. Cruciform monogram resolving as ‘of Theodotos’. Ø 25 mm; mass 4.49 g (nomisma).

40. 1923,1107.1. Cruciform monogram resolving as ‘of Timotheos’. Ø 21 mm; mass 2.02 g (semissis).

Type D: Arab-Byzantine weights

41. 1980,0611.52. Bust of an eparch enclosed by a debased Greek or Cufic inscription. Ø 23 mm; mass 4.27 g (nomisma).

42. 1986,0406.14. Bust of an eparch enclosed by a debased Greek or Cufic inscription. Ø 23 mm; mass 3.27 g (nomisma).

43. 1980,0601.51. Bust of an eparch enclosed by a debased Greek or Cufic inscription. Ø 23 mm; mass 4.18 g (nomisma).

44. 1980,0611.71. Indistinct frontal bust. Ø 16 mm; mass 1.37 g (tremissis).

Acknowledgements

The authors would like to thank the many colleagues at the British Museum who assisted with this work. They also thank two anonymous reviewers and Daniela Rosenov (University College London) for helpful comments and discussion.

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References


Notes

1. The only published technical study of ancient glass weights is that of eighth-century Arabic glass weights by Matson, in which he described flakes of iron scale on the reverse or folded into the glass [5, 6]. An as-yet unpublished report by Freestone of some of the Byzantine glass weights in the British Museum’s collection remarks that “although present in some cases, iron scale is considerably less frequent on the Byzantine weights . . . and thus there is likely to have been some difference in the tools or operating procedures used by the Byzantine and Islamic artisans, although the significance and precise nature of this difference is not yet fully understood” [8].

2. The transition from box to cruciform monogram can be observed at an early stage on the brass collars and marble capitals of three churches in Constantinople. At Hagia Sophia, it is the imperial monogram of Theodora that changes from the box to the cruciform type, while Justinian’s remains of the box form. Hagia Sophia was completed by AD 337, so the change presumably occurred in the later years of its construction, probably AD 435–436. Similar cruciform monograms of Theodora can be seen at the Church of Saints Sergios and Bacchos (completed by AD 356) and at Hagia Irene (rebuilt by AD 540).

3. It is noteworthy that some of the earliest Byzantine box monograms are extremely crude and these weights may represent the prototypes of the more developed box monograms.
Ancient Egyptian funerary food: new insights

Caroline Cartwright and John H. Taylor

SUMMARY Over 20 examples of ancient Egyptian funerary bread in the British Museum collections were examined using optical microscopy and variable pressure scanning electron microscopy in order to characterize the components of the bread and assess whether or not it might have been edible and similar to the bread consumed in households of that time. From the outset it was clear that many of the specimens were quite dissimilar. Some contained large quantities of cereal chaff from crop-processing waste and might be considered unpalatable or even inedible by modern standards. Not all were in this category; many other examples had whole cereal grains present, mostly barley, although wheat also occurred. Some specimens had whole fruits or fruit pulp added to the bread ingredients. Examples that displayed a crystalline appearance due to the presence of *Pistacia* sp. resin may have undergone treatment with this substance in the context of funerary rituals.

Comparative identifications were also carried out on various funerary fruits including dates, sycomore figs, dom palm fruits, pomegranates and grapes, as well as cereal grains (barley and wheat) and seeds. While many of the cereals and fruits were in a good state of preservation (owing to the particular environmental conditions within the tombs), some of the bread had been extensively eaten by insects, whose remains were still present.

Introduction

There are many examples of funerary foodstuffs from ancient Egyptian tombs in the collection of the Department of Ancient Egypt and Sudan at the British Museum, but this contribution is not intended to be a comprehensive overview of all this material. The primary focus here is on funerary bread, which has long been the subject of interest and speculation as to its composition, purpose and ritual significance. A preliminary investigation of some funerary foodstuffs using optical microscopy was carried out previously on selected bread, cereal grains, fruits and seeds [1].

Prompted by the British Museum’s exhibition *Ancient Lives: New Discoveries* in 2014–2015, 19 examples of bread were examined using the variable pressure scanning electron microscope (VP SEM). The objectives of this examination included: characterizing the components of the bread; assessing whether or not the bread might have been edible and similar to the bread consumed in households of that time; noting any particular inclusions, textures, features or oddities; and evaluating whether or not much sand was present (either as a result of processing the cereals using grindstones or as an added filler). In addition, selected examples of other funerary food and organic offerings were examined in order to provide specific identifications of these materials within the context of ancient Egyptian social and religious practices, Table 1.

Provenance, context and date

The food samples selected for study came from a number of different sources. The majority were acquired from European (mainly British) travellers who spent lengthy periods in Egypt in the nineteenth century and formed collections of antiquities: these collectors included John Gardner Wilkinson, Henry Salt, James Burton, Edward William Lane, Joseph Sams, Anthony Charles Harris, Greville Chester, Sir Frederick Henniker, Henry Stobart, Giovanni Anastasi and the Duc de Blacas d’Aulps, Table 1. Some items were acquired at the public auction of Salt’s and Burton’s collections in 1835 and
Table 1. Details of the bread and other funerary foodstuffs examined in this study

<table>
<thead>
<tr>
<th>Registration number</th>
<th>Objects</th>
<th>Provenance and acquisition details</th>
<th>Identifications and observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA5341</td>
<td>Two loaves of bread in a basketry dish</td>
<td>Burton 1836, lot 249 (Thebes)</td>
<td>Hordeum sp., barley grains, starch grains and a baking 'bubble' where air escaped through the dough when it was being heated</td>
</tr>
<tr>
<td>EA5343</td>
<td>Triangular bread</td>
<td>Burton 1836, lot 249 (Thebes)</td>
<td>Triticum sp., wheat and Hordeum sp., barley grains with assorted cereal chaff fragments</td>
</tr>
<tr>
<td>EA5344</td>
<td>Bread fragment</td>
<td>Anastasi</td>
<td>Much cereal chaff</td>
</tr>
<tr>
<td>EA5345</td>
<td>Bread</td>
<td>Wilkinson</td>
<td>SEM images show a small circular (raised) decorative area; also fine ash particles on surface; plus Hordeum sp., barley grains and much cereal chaff</td>
</tr>
<tr>
<td>EA5347</td>
<td>Bread fragments</td>
<td>Wilkinson</td>
<td>Hordeum sp., barley grains, cereal chaff, Ziziphus spina-christi (nabk) fruit pulp and starch grains</td>
</tr>
<tr>
<td>EA5348</td>
<td>Bread fragment</td>
<td>Sams 1834</td>
<td>Considerable cereal chaff; the surface of the bread now has much detrital material and (inactive) fungal hyphae</td>
</tr>
<tr>
<td>EA5349</td>
<td>Bread</td>
<td>Sams 1834</td>
<td>Cereal chaff present</td>
</tr>
<tr>
<td>EA5350</td>
<td>Bread fragment</td>
<td>Sams 1834</td>
<td>Cereal chaff present</td>
</tr>
<tr>
<td>EA5351</td>
<td>Bread fragment</td>
<td>Sams 1834</td>
<td>Much cereal chaff; the surface of the bread shows considerable detrital material, modern fibres and recent crystal growth</td>
</tr>
<tr>
<td>EA5352</td>
<td>Bread fragment</td>
<td>Sams 1834</td>
<td>Ziziphus spina-christi (nabk) fruits and fruit fragments with cereal chaff</td>
</tr>
<tr>
<td>EA5353</td>
<td>Biscuit-like bread</td>
<td>Sams 1834</td>
<td>Ash particles and impressions of Phoenix dactylifera (date palm) leaf matting on the bread surface</td>
</tr>
<tr>
<td>EA5354</td>
<td>Bread with incised lines, fragment</td>
<td>Sams 1834</td>
<td>Anomalous mixture with Hordeum sp., barley grains and cereal chaff present, but one of the barley grains has a modern fibre looped behind it. The bread surface shows much detrital material and modern fibres</td>
</tr>
<tr>
<td>EA5355</td>
<td>Bread or biscuit fragment</td>
<td>Sams 1834</td>
<td>Hordeum sp., barley grains and cereal chaff in a very crystalline matrix (Pistacia sp. resin)</td>
</tr>
<tr>
<td>EA5356</td>
<td>Bread fragment</td>
<td>Sams 1834</td>
<td>Many Hordeum sp., barley grains present (and voids where they were); also cereal chaff</td>
</tr>
<tr>
<td>EA5357</td>
<td>Bread fragment</td>
<td>Sams 1834</td>
<td>Much cereal chaff</td>
</tr>
<tr>
<td>EA5359</td>
<td>Bread fragment</td>
<td>Sams 1834</td>
<td>Many Hordeum sp., barley grains and much cereal chaff</td>
</tr>
<tr>
<td>EA5360</td>
<td>Bread in shape of leaf</td>
<td>Lane 1842</td>
<td>Many Hordeum sp., barley grains and much chaff; mix also contains Ziziphus spina-christi (nabk) fruit pulp</td>
</tr>
<tr>
<td>EA5361</td>
<td>Bread fragment</td>
<td>Lane 1842</td>
<td>Cereal chaff present</td>
</tr>
<tr>
<td>EA5362</td>
<td>Bread in shape of crocodile's head</td>
<td>Lane 1842</td>
<td>Cereal chaff present with some fragmented Triticum sp., wheat grains</td>
</tr>
<tr>
<td>EA5384</td>
<td>Fragment of cake-like bread</td>
<td>Lane 1842</td>
<td>Ziziphus spina-christi (nabk) fruits and fruit pulp, Ficus sycomorus, (sycomore fig) seeds, Hordeum sp., barley grains and cereal chaff</td>
</tr>
<tr>
<td>EA5391</td>
<td>Bread fragments (found in basket EA 5391)</td>
<td>Henniker</td>
<td>Bread extensively eaten by insects; beetles still present in many of their chambers</td>
</tr>
<tr>
<td>EA15744</td>
<td>Bread</td>
<td>Chester (Thebes)</td>
<td>Crystalline appearance with Pistacia sp. resin present</td>
</tr>
<tr>
<td>EA15745</td>
<td>Bread fragment</td>
<td>Chester (Thebes)</td>
<td>Hordeum sp., barley grains and assorted cereal chaff plus some Ziziphus spina-christi (nabk) fruit pulp and starch grains</td>
</tr>
<tr>
<td>EA35948</td>
<td>Bread</td>
<td>No history</td>
<td>Cereal chaff present</td>
</tr>
<tr>
<td>EA35974</td>
<td>Bread fragments</td>
<td>Wilkinson 1834</td>
<td>Hordeum sp., barley grains and cereal chaff</td>
</tr>
<tr>
<td>EA35976</td>
<td>Bread fragments</td>
<td>Wilkinson 1851 (Thebes)</td>
<td>Mixture of fragmented Hordeum sp., barley grains and cereal chaff</td>
</tr>
<tr>
<td>EA36192</td>
<td>Bread fragments</td>
<td>Calvert 1870</td>
<td>Hordeum sp., barley grains and much barley chaff mixed in with ash particles and tiny pebbles (unlike the other examples where there is little quartz sand)</td>
</tr>
<tr>
<td>EA36193</td>
<td>Torpedo-shaped loaf</td>
<td>Sams 1834 or Burton 1836</td>
<td>Cereal chaff and Hordeum sp., barley grains present; possibly also Lolium temulentum, darnel</td>
</tr>
<tr>
<td>EA36195</td>
<td>Bread</td>
<td>Wilkinson 1834</td>
<td>Cereal chaff present</td>
</tr>
<tr>
<td>EA3563</td>
<td>Dish with possible mashed barley</td>
<td>Stobart 1848 (Thebes)</td>
<td>Mixture of fragmented Hordeum sp., barley grains and cereal chaff</td>
</tr>
<tr>
<td>EA35977</td>
<td>Cereal grains</td>
<td>No history</td>
<td>Hordeum sp., barley and Triticum sp., wheat grains</td>
</tr>
<tr>
<td>EA5371</td>
<td>Fruits</td>
<td>Sams</td>
<td>Hyphaena thebaica (dom palm) fruits with the outer surface removed</td>
</tr>
<tr>
<td>EA5372</td>
<td>Fruits</td>
<td>No history</td>
<td>Phoenix dactylifera dates</td>
</tr>
<tr>
<td>EA5374</td>
<td>Bowl with fruits</td>
<td>Sams 1834 and Burton 1836</td>
<td>Vitis vinifera grapes</td>
</tr>
<tr>
<td>EA5377–5379</td>
<td>Fruits and seeds</td>
<td>Lane 1842 (5378)</td>
<td>Items not individually numbered but include Ziziphus spina-christi, (nabk) fruits and Ricinus communis (castor-oil plant) seeds</td>
</tr>
</tbody>
</table>
Ancient Egyptian funerary food: new insights

1836 respectively, and the others through private sale or donation to the British Museum. Many of the items were reported to have been found in tombs in the necropolis of ancient Thebes (modern Luxor), but precise details of the contexts for the finds are rare and foods that were found together were often dispersed, passing into the hands of different collectors without record of their original place of discovery. Fortunately, the integrity of one such group was carefully retained, allowing it to be described as follows when it formed lot 249 in the sale catalogue of Burton's collection:

A PREPARED FEAST, emblematic of the profession of the DECEASED, consisting of – TWO DUCKS or Water-fowl, upon the ORIGINAL STAND on which they were found, composed of cane and the papyrus plant; accompanied with a DESERT [sic], comprising Cakes of different forms, made of coarsely ground corn; and Fruits, namely Dom Apples, Pomegranates, Dates, Onions, Raisins, and Figs of the Sycamore Tree. These MOST EXTRAORDINARY FUNERAL OBJECTS were found in a PRIVATE TOMB at THEBES [2].

This complete group was acquired for the British Museum and many of the specimens of bread and fruits of which it was composed are included in the present study, Figure 1 and Table 1. Although early nineteenth-century auction catalogues are often vague as to the provenance of Egyptian antiquities, a few – such as those of the collections of Henry Salt (1835) and Giovanni d’Athanasi (1837) – included this type of data,
which can be supported by other archival sources. The Burton sale of 1836 belongs to this select group that includes circumstantial details of the discovery of some items, for example lots 232 and 233 [2].

A further seven lots (250–256) in Burton’s sale comprised food items comparable to those of lot 249, described as “having formed portions of similar collections” [2]. Indeed, the discovery of well-preserved food specimens in Theban tombs was often mentioned in contemporaneous accounts of early nineteenth-century travellers and these are likely sources for many of the other examples considered here, although in only a few cases (EA 5363, EA 15745, EA 35976, EA 35938, EA 35941, EA 35953 and EA 14959) is there clear supporting evidence from sale catalogues or museum registers for a Theban provenance.

More recent excavations conducted under controlled conditions in the twentieth century have brought to light further deposits of foodstuffs in graves and tombs. These include specimens from the Late Predynastic period at Hierakonpolis [3], an exceptionally well-preserved ‘funeral meal’ laid out next to the burial pit in an undisturbed tomb of the Second Dynasty at Saqqara [4], and numerous examples from Thebes, dating to the New Kingdom. This last group date mainly to the Eighteenth Dynasty [5; pp. 210–211] and are particularly well represented at Deir el-Medina [6; pp. 106–110 and 147–202]. The range and quantities of foodstuffs found with burials in the ‘Eastern Cemetery’ at Deir el-Medina (chiefly bread, cooked meats, fish and fruits) offer close parallels to Burton’s ‘feast’ and seem to represent the components of a ‘balanced’ meal for the dead. It is possible (though unproven) that the Burton group came from the same part of the Theban necropolis, which was intensively targeted by European collectors and their agents in the 1820s and 1830s. A date in the New Kingdom is also highly probable, since the custom of placing food in the tomb appears to have declined in later periods [5; p. 220; 7; pp. 379–380].

The offering of foodstuffs to deities is also abundantly documented in ancient Egyptian religious iconography, but because of the transitory nature of the offering practice is much less well attested archaeologically. However, the present study includes three specimens of different fruits that were excavated by the Egypt Exploration Fund (now Society) in a shrine dedicated to the goddess Hathor at Deir el-Bahri and are perhaps to be considered as offerings to the divinity; for the context of these offerings, see [8; pp. 13–17].

Provisioning the dead

The concept of an afterlife was evidently well developed in Egypt by the time of the emergence of writing in the late fourth millennium BC, with both practical and magical approaches being used to care for the dead. Nourishment was one of the fundamental needs that ancient Egyptian mortuary practice sought to fulfil. The earliest and simplest response to the challenge of feeding the dead was to place food and drink in the grave, but since an inexhaustible supply was deemed necessary, such offerings could be no more than tokens. Alongside this practice, magical methods were used to perpetuate the supply of provisions to the dead. One such method was the recitation of mortuary liturgies, notably the ‘offering formula’ (hetep di nesu), which was believed to supply the recipient with 1000 loaves of bread and 1000 jugs of beer, besides oxen, wildfowl and other essentials. By inscribing the ritual words in the tomb or by creating images of foodstuffs and of servants producing them, the magic was eternalized and placed at the direct disposal of the occupant of the tomb. Yet despite a strong adherence to these magical practices, the custom of depositing real foodstuffs in the grave persisted for long periods and environmental conditions favourable to their preservation have resulted in a substantial body of material being available for study [9; pp. 92–103].

The symbolic character of these offerings raises questions. In no sense was there an expectation that the reborn dead would physically consume the loaves and cakes that were left in their tombs, which raises the question of whether they were truly representative of the diet of the living [10; p. 542]. Some bread from tombs has been reported to be heavily contaminated with chaff and has been considered perhaps inedible [11; pp. 256–258]. If it was considered edible, a secondary question arises: how far might these contaminants have been responsible for the heavy wear that has regularly
been observed on the teeth of ancient Egyptian skulls [12, 13]? Further study of the incidence of dental wear in ancient Egyptian populations is needed to address this question, but some surveys have drawn attention to regional variability in the occurrence of attrition and to an apparent decrease in the condition over time. Changes in diet and techniques of food preparation have been highlighted as potentially influential factors in this area of investigation [14].

Assessing the significance of food remains found in tombs requires a circumspect approach, particularly as comparable material that is known to have formed part of the diet of the living is scarce. At Upper Egyptian sites such as Adaima and Hierakonpolis (mid-to-late fourth millennium bc) archaeobotanical studies have made it possible to compare the remains of food substances retrieved from preparation vats, from the abdominal contents of well-preserved naturally mummified bodies, from coprolites and from traces embedded in calculus on teeth [15–17]. Although studies of this type of evidence are relatively new, preliminary findings at Hierakonpolis have already shown that gut contents from human remains included substantial quantities of husk fragments of emmer wheat that had not been separated from the grains during the preparation process. These findings related particularly to adult burials, whereas the remains of children showed evidence of an intentionally more refined ‘baby food’, consisting of pure grains without husk fragments [16; p. 425]. It has been proposed, therefore, that at all periods standard practice dictated that “emmer wheat grains were kept in their husks to protect them from insects and to preserve their freshness” [16; p. 425]. In view of this, the possibility remains real that the ‘tomb breads’ studied here could have been eaten, despite the quantities of processing waste and other inclusions that they contained.

**Methods**

Optical microscopy was carried out using a Leitz Aristomet biological microscope with reflected light at magnifications ranging from ×10 to ×200. The operating conditions of the VP SEM (Hitachi S-3700N) allowed direct examination of the surface and matrix of the bread fragments without any need for preparation, sampling or coating, thus avoiding damage or contamination. The backscatter detector was used at 20 or 15 kV, with an average working distance of 25 mm, at magnifications ranging from ×10 to ×600 and with a partially evacuated (40 Pa) chamber.

The large size of the Hitachi S-3700N VP SEM chamber (which can accommodate a specimen size of up to 300 mm in diameter and 110 mm high at an analytical working distance of 10 mm) permitted intact loaves of bread to be examined in certain instances. If, however, no damaged areas that revealed the interior (matrix) of the bread were present, only the surfaces could be characterized.

Publications on Egyptian (and Old World) flora (for example [18–22]) were used for evaluating the distribution and status of the plants identified.

**Results and discussion**

**Bread**

Table 1 contains the details of the 29 bread samples that were examined. Macroscopically as well as microscopically it was obvious that many of the bread specimens are quite dissimilar. Some appear open and ‘porous’ while others contain a high proportion of cereal chaff (for example EA36192 and EA35976), possibly from crop-processing waste or residues from brewing beer [10; p. 564]. By modern standards, such high-chaff bread might be considered unpalatable or even inedible, for example EA36192, Figure 2. Not all were in this category, however. Many of the edible examples have whole cereal grains present, the majority of which are barley (for example EA36193), but wheat also occurs, most of which is emmer [10, 23]. Figure 3 shows an example of an intact cereal grain in EA36193, most likely to be small barley or a narrow form of darnel, *Lolium temulentum*. There is often considerable variability in the microstructure of a single loaf of bread, a feature also observed by Samuel [10; p. 564]. It is still an open question as to whether or not the bread found in the tombs is entirely representative of the bread consumed domestically; Samuel considers tomb bread “unlikely to be fully representative of the daily fare” [24; p. 7].
Cereal grains are often accompanied by fragments of cereal stems or leaves, both on the surface of the bread and within the bread matrix. Many of these display phytoliths (plant silica bodies), which can be helpful in determining cereal type, for example EA5347, Figure 4. Minute particles of silica from phytoliths are very common in these bread specimens and if these reflect the domestic bread of the time, this silica could have affected the teeth of anyone eating it. Although it is widely asserted that the teeth of ancient Egyptians were frequently severely worn down as a result of eating gritty bread made with flour containing sand and other inorganic impurities [25; p. 75], few quartz sand grains were observed in the bread specimens studied. In this context, during recent fieldwork in Sudan, Philippa Ryan found that local village bread (beledi: Figure 5) was made with a liberal surface dusting of chaff debris, which is believed to stop the bread burning in the oven [26]. This may not necessarily explain the large proportion of chaff debris within the matrix of the tomb bread, as well as on the surface, but it is worthy of note nonetheless.

Some specimens had whole fruits or fruit pulp added to the bread ingredients. Evidence for this can be seen from fig seeds (or the voids where they were located), for example EA5384 (Figure 6), or fruit skins from *Ziziphus spina-christi* (Christ’s thorn), for example EA5352, Figure 7. These may be categorized in the same way as Hepper described for the loaves of bread from Tutankhamun’s tomb, i.e. as fruit loaves or cakes [27]. The VP SEM also revealed baking ‘bubbles’ where air escaped through the dough when it was heated, for example EA5341 (Figure 8), and starch grains, for example EA5347. In the earlier British Museum study starch was identified by Fourier transform infrared (FTIR) spectroscopy in EA15745 [1].

Some bread specimens contain material with a crystalline appearance (for example EA5355), identified by Thickett in an earlier FTIR analysis (of EA15744) as *Pistacia* sp. resin [1]. Ash particles and the possible impressions of date palm leaf matting on bread surfaces were observed in some examples, for example EA5333. Perhaps the most surprising results came from fragments of bread (EA5391) that were originally
in a basket, Figure 9. VP SEM images of fragment EA5391c confirmed the visual impression that the bread had been extensively eaten by insects, with beetles found still to be present in many of their chambers, Figure 10.

**Other foodstuffs and organic offerings**

Table 1 also lists identifications that were carried out on various funerary fruits including dates, sycomore figs, dom palm and argun palm fruits, pomegranates, grapes and nabk (Christ’s thorn) fruits, as well as cereal grains (barley and wheat), lentils and vetch seeds. Their presence and significance in ancient Egypt has been well aired in the literature, for example [10, 23, 27–31], so only salient points will be highlighted here.

Specimens EA5347, EA5352, EA5353, EA5360, EA5384 and EA15744, which are described as bread, biscuit-like bread and cake-like bread, all contain nabk fruits or fruit pulp within the dough mixture. Whole nabk fruits are present in EA5377–5379 (items not individually numbered), EA35948 and EA35978. Nabk fruits have a rather astringent taste but contain vitamin C, carbohydrates, protein, calcium, iron and B vitamins, and are still eaten fresh or dried in Egypt today by both people and animals [31].

Specimen EA5353, a biscuit-like bread, has impressions of date palm (*Phoenix dactylifera*) leaf matting on the bread surface, but in the specimens studied, no breads contained fragments of date fruits. However, date fruits are present in EA5372, EA35950, EA35967–35970 and EA41178. Murray notes that there is a wide diversity in shape and quality among date fruits from both ancient and modern contexts [31], but their nutritional value coupled with their high sugar content makes them attractive for the human diet. Almost every part of the *Phoenix dactylifera* palm has a useful purpose, a fact that outweighs the complicated pollination procedures required for its sustained cultivation.

No fragments of dom palm (*Hyphaene thebaica*) fruits were found in any of the bread specimens studied, but fruits are present in EA5371, EA35931, EA35935–5938, EA35940, EA35941, EA35953, EA35958–35961, EA35966 and EA41175, either whole or with their outer skin removed. Underneath this thin hard brown layer is the edible, fibrous, sugary mesocarp (which has a gingerbread smell) containing a hard white seed [31]. In addition to its fruits, most components of the dom palm have important uses as well as sacred significance [18, 28].

Specimens EA35955 and EA35956 contain argun palm (*Medemia argun*) fruits. This palm is most valued for its leaves, which are used for matting and ropes. Its fruits are almost inedible unless softened through burial in the ground over a long period, although it is unclear whether this practice was known or used in ancient Egypt [31]. Nonetheless argun palm fruits have been found as tomb offerings and this fact contributes to the discussion as to whether any or all of funerary food offerings, including bread, were required to be representative of the human diet of the time, or whether sacred, religious or cultural perceptions associated with particular trees, plants and their products overrode their comestible properties.

A fragment of cake-like bread (EA5384) contains sycomore fig (*Ficus sycomorus*) seeds (Figure 6), in addition to nabk fruits, barley grains and chaff; whole sycomore fig fruits are present in EA35945 and EA41180. Another extremely important tree in ancient Egypt, *Ficus sycomorus* was highly valued, not only for its fruits, wood and other useful elements, but also for its religious associations. As Murray observes, it can be difficult to distinguish between ancient specimens of
since the evidence base currently remains biased towards from settlement sites or other domestic environments, observed on ancient Egyptian teeth. It is to be hoped that have contributed to the types of dental wear that have been present in foodstuffs that were eaten and could, therefore, being the case, the dense particles that have been detected abdominal contents indicates that bread ‘contaminated’ with of evidence from palynology, phytolithology and analyses of Variable pressure scanning electron microscopy and associ-ated analyses of the bread samples revealed considerable

Specimen EA5374 consists of a pottery dish from Thebes with 285 grapes (*Vitis vinifera*). They have a dried and shrivelled appearance that has in the past led to them being described as raisins and microscopically they appear similar to raisins identified from an early Bronze Age context at Tell es-Sa‘idheh in Jordan [32]. Although the area of earliest domestication and cultivation of *Vitis vinifera* is still not decided, it seems that the domesticated form was introduced into Egypt from the Levant, probably in the Predynastic period [21]. Evidence for the importance of grape cultivation in ancient Egypt comes from the finds, textual evidence and depictions of harvesting and processing; for details see the comprehensive review of viticulture and wine production in Egypt by Murray, Boulton and Heron [33].

Specimens EA5377–5379 are not individually numbered, but each contains seeds from the castor oil plant (*Ricinus communis*). Although the raw seeds of the castor oil plant are toxic due to the presence of ricin, they are a source of useful oils [34]. Specimen EA35954 contains a small pomegranate (* Punica granatum *) fruit, another species not native to Egypt, but probably traded from the Levant. In addition to edible uses, pomegranates can be used medicinally and for tanning or dyeing; they have also been regarded as sacred or fertility symbols in many areas [31].

In many North African and Middle Eastern diets, in ancient as well as modern periods, pulses provide an important source of protein in a diet in which meat is not regularly consumed. Although there are many examples of evidence for pulse use, here only one such is included. Specimen EA35961 contains lentils (*Lens sp.*), which can be ground for flour, eaten raw or cooked, and preserved through drying or salting.

While broad beans (*Vicia faba*) are an important food pulse staple, the *Vicia* sp. seeds found in EA14959 are more likely to represent a vetch grown for animal fodder.

Conclusions

Variable pressure scanning electron microscopy and associated analyses of the bread samples revealed considerable variability in the constituents and proportions of chalk to ‘pure’ grain contained within the dough. The growing body of evidence from palynology, phytolithology and analyses of abdominal contents indicates that bread ‘contaminated’ with processing waste was actually consumed by the living. That being the case, the dense particles that have been detected in the bread in the present study are also likely to have been present in foodstuffs that were eaten and could, therefore, have contributed to the types of dental wear that have been observed on ancient Egyptian teeth. It is to be hoped that further studies of this type might focus on bread samples from settlement sites or other domestic environments, since the evidence base currently remains biased towards material from funerary contexts. Future investigations might also address issues such as the spatial distribution of contaminants in loaves (e.g. whether on the surface alone or throughout the material) and the relevance of this to food processing techniques.

Acknowledgements

The authors thank Philippa Ryan for drawing their attention to the current, local production of chaff-rich bread in Sudan and providing the photograph in Figure 5. Thanks are due to Alan Clapham for advice regarding the grain seen in the sample in Figure 3.

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References


Notes
1. Registration numbers: bread (EA5344, EA5349, EA5350, EA5352, EA5357, EA5362, EA5364, EA5367, EA35974 and EA35975); cereal grains (EA53977); fruits (EA5371, EA5372, EA5374, EA5377–337); EA53931, EA53935–33938, EA53940, EA53941, EA53946, EA53948, EA53990, EA53993, EA35954, EA53958–33961, EA53966–33970, EA41175, EA41178, EA41180, EA53953, EA35956 and EA53978); and seeds (EA41959 and EA53990).
3. A fig is not actually a fruit; it is an inflorescence (a cluster of many flowers and seeds contained inside a bulbous stem). Technically, the seeds are the ovaries of the fig.
Tools for eternity: pre-Columbian workbaskets as textile production toolkits and grave offerings

Karen E. Price, Catherine Higgitt, Thibaut Devièse, Colin McEwan and Bill Sillar

SUMMARY Small workbaskets containing assemblages of tools and materials used in textile production are fairly common in later pre-Hispanic funerary contexts in Andean coastal regions. Many of these baskets that are now preserved in museum collections were collected in the late nineteenth and early twentieth century. Although most lack firm provenance and contextual information, they nevertheless offer potential insights into textile production. The contents of such workbaskets present an opportunity to investigate coastal spinning, textile traditions and various stages in the organization of textile production, and to consider the items used by one individual artisan during his or her textile production activities. The inclusion of workbaskets in funerary contexts also raises questions about the degree to which their contents reflect contemporaneous textile production practices.

A specific methodology to describe and evaluate the integrity of the assemblages has been developed and here the results of a detailed empirical analysis of the contents of 13 workbaskets, drawn mainly from the collections of the British Museum (BM) and the Musée du Quai Branly (MQB), Paris, are presented. A developing database of 349 baskets identified in museum collections and/or reported in publications is also included in this work. The study focused on the spinning tools and yarns (including their spin, ply and dyes) associated with the baskets as the most suitable means to determine whether the workbaskets emanated from a single coastal textile tradition and to provide insights into textile production. This study contributed to the ‘Andean Textiles: Organic Colourants, Biological Sources and Dyeing Technologies’ project undertaken at the BM in collaboration with the MQB and has focused on improving understanding of pre-Columbian textiles and the cultures that produced them.

The analysis of the contents of the 13 workbaskets reveals similarities in their form and contents, with all generally containing a consistent range and distribution of tools and materials, indicating that a standardized coastal ‘toolkit’ may be identified. Evidence from the spin, fibre type and colours used, and from iconography, suggests that the workbaskets conform to central and south coast textile traditions. While the utilitarian function of the workbaskets is clearly revealed, and the assemblages appear to be largely intact, the modifications associated with their subsequent use as grave goods together with their social and symbolic role in funerary contexts are also considered. The practice of including such workbaskets in burial contexts appears widespread, particularly on the central coast during the Late Intermediate period onwards, but evidence is also considered from the highlands that suggests it represents a rather broad ranging and persistent practice spanning a large and culturally diverse region. This research also highlights a number of future research avenues that, together with the body of comparative data presented here, may help to tie these objects more closely to specific cultures, time periods and regions.

Introduction Pre-Columbian textiles are well known throughout the academic and museum world for their complex structures and techniques as well as their vibrant imagery. Ancient Andean textiles were variously deployed as elements of clothing and costume, tribute, currency and grave goods. The skilful combination of materials, form, colours and iconography served to signal gender, age, status and other vital social attributes, and could also incorporate administrative and calendrical information [1–6]. The significance of textiles in ancient Andean
life is portrayed in both colonial ethnohistorical accounts (e.g. [7, 8]) and in the preserved artefacts.

By considering a range of textile data and technical features (including garment types, imagery and design layout, textile structure/technique and construction, colours and patterns, fibre, and yarn spin), textile specialists are able to recognize at least four regional textile styles in the Andean region—a region encompassing the modern territories of Peru, Chile and Bolivia and dominated by the Andes mountains [9–13]. Frame et al. give the major regional traditions as the northern, the central highland, the centre-south (southern highland) and the tradition of the central and south coast [14]. The regional diversity does not, however, imply cultural isolation [15]. Further, within the same overall regional textile tradition, variations in specific features may allow distinct cultural styles to be recognized, for example Chancay and Ychsma (or Pachacamac) styles in the Late Intermediate period can be recognized within the central and south coast tradition [14]. The degree of understanding of the different textile traditions is closely linked to the availability of securely provenanced and archaeologically excavated material from the region. Study of the technical features of surviving textiles can provide insights into their production and the spinning and weaving techniques used, particularly when combined with ethnographic research [16] and associated archaeological evidence in the form of tools and other materials involved in textile production.

In 2011, the ‘Andean Textiles: Organic Colourants, Biological Sources and Dyeing Technologies’ project, funded by the Leverhulme Trust, was initiated at the British Museum (BM), in collaboration with the Musée du Quai Branly (MQB), Paris [17]. The project’s main aim was to improve understanding of Andean textiles and the cultures that produced them through the analytical study of dyes, thereby complementing studies focused on textile styles and technical features. Reflecting the strengths of the BM and MQB Andean textile collections, the focus was on textiles from the south coast region ranging in date from the Early Horizon to Late Horizon and on Late Intermediate period textiles from the central coast, Table 1 [13]. The arid environment prevailing along the Pacific coasts of Peru and Chile is conducive to the preservation of textiles and a range of other perishable organic materials. These include small workbaskets, of which the BM and MQB collections also contain a number, holding a range of tools and materials associated with textile production, including large quantities of dyed fibres and yarns. Weaving implements such as workbaskets, spindles and looms often accompany late pre-Hispanic burials among these coastal cultures, particularly on the central coast [1, 18]. Where the contents of the baskets are described, these include raw fibre, balls and skeins of cotton and camelid fibre yarn (dyed and undyed), combs, spindles, spindle whorls, tapestry needles, sewing needles, carved sticks, textiles and bobbins or shuttles for weaving [18–20]. Although often referred to as ‘weavers’ workbaskets’, the materials and tools found within them are also associated with other stages of textile production such as spinning, sewing and embroidery. Additional items whose functions have not yet been recognized may also be present, possibly including grave goods not linked to textile production. The less specific term ‘workbasket’ has therefore been used in this article.

Although, like many of the textiles in the BM and MQB collections, the workbaskets lack secure provenance, they are believed to be from coastal contexts (with the majority attributed to the central coast) and to be broadly contemporaneous with the Late Intermediate textiles included in the ‘Andean Textiles’ project. Within the context of this project, study of the tools within the workbaskets offered potential for investigating coastal spinning and textile traditions and the various stages of textile production. Moreover, the workbaskets present a unique opportunity to consider tools and materials used by one individual during his or her textile production activities. Finally, the dye analysis undertaken as part of the project necessitated the development of analytical procedures optimized for the molecular-level characterization of the wide range of colourants associated with archaeological Andean textiles. The fibres and yarns within the workbaskets offered ready access to relatively large quantities of a very wide range of differently coloured material that was easy to sample and provided a valuable complement to the textiles, as well as an opportunity to ensure the robustness of the analytical procedures. The preservation of the material within a purpose-built container also reduced the chances of contamination. It was also hoped that dye analysis of materials from the workbaskets might help to associate the baskets with particular regional textile traditions. However, the inclusion of workbaskets in funerary contexts suggests that they may be invested with added social, symbolic or personal significance that transcends purely utilitarian functions.

Pre-Columbian workbaskets are mentioned periodically in the literature [21], and were included in the early work of Mason [22, 23], drawing on the work of Reiss and Stübel at

### Table 1. Chronology and predominant Peruvian coastal art styles and cultures, based on [13]

<table>
<thead>
<tr>
<th>Chronological period</th>
<th>North coast</th>
<th>Central coast</th>
<th>South coast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Horizon (700 bc–0)</td>
<td>Cupisnique</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Intermediate (0–ad 650)</td>
<td>Moche</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Horizon (AD 650–1000)</td>
<td>Lambayeque</td>
<td>Wari</td>
<td></td>
</tr>
<tr>
<td>Late Intermediate (AD 1000–1450)</td>
<td>Chimu</td>
<td>Chancay</td>
<td>Ica</td>
</tr>
<tr>
<td>Late Horizon (AD 1450–1550)</td>
<td>Inca</td>
<td>Inca</td>
<td>Inca</td>
</tr>
<tr>
<td>Early Intermediate (0–ad 600)</td>
<td>Nasca</td>
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<tr>
<td>Middle Horizon (AD 50–800)</td>
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<tr>
<td>Late Horizon (AD 800–1350)</td>
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</table>

<table>
<thead>
<tr>
<th>Art style/culture</th>
<th>North coast</th>
<th>Central coast</th>
<th>South coast</th>
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<tbody>
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<td>Early Horizon</td>
<td>Cupisnique</td>
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<tr>
<td>Early Intermediate</td>
<td>Moche</td>
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<td>Middle Horizon</td>
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<td>Ica</td>
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<tr>
<td>Late Horizon</td>
<td>Inca</td>
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</tbody>
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...
Ancón [24], but they remain poorly studied and discussed (at the time of writing this paper, the authors know of some 18 papers, which refer to 48 individual baskets). They are often mentioned only in passing, although a number of authors are starting to consider the baskets in more detail [19, 20, 25, 26]. The most detailed study of the tools and materials associated with coastal workbaskets to date was undertaken by Tiballi on the contents of 12 Late Horizon workbaskets from the Cemetery of the Sacrificed Women at Pachacamac on the central coast of Peru [18]. Although under Inca control, the site exhibits coastal (rather than highland) textile traditions and evidence for high status textile production in a workshop setting.

As dedicated receptacles, the baskets provide a context for the assemblage of artefacts inside them. In choosing to include material from workbaskets within the ‘Andean Textiles’ project, a key consideration was whether the workbaskets and their contents reflected everyday practice or were specially constituted burial offerings. Similarly, the integrity of the basket contents was of concern as material could have been added or removed by looters, excavators, dealers or collectors. It was also of interest to consider whether the workbaskets all emanate from a single textile tradition or if distinct regional traditions can be distinguished. A research methodology was therefore adopted for this study to assess the inherent biases in assemblages that lack a secure archaeological context, and which may have been modified following excavation, based on comparison with other known examples.

The majority of Andean collections in European and North American museums were acquired from “travellers, traders, administrators and antiquarians of the nineteenth and early twentieth century” [26; p. 358], with little material coming from securely recorded archaeological excavations [1, 20; p. 126]. Many workbaskets within these collections have no accurate provenance although the majority are associated with large central coast cemeteries [25–27], including those at Ancón (north of Lima) [28, 29], Pachacamac (south of Lima) and Zapallar (also known as Zapallan, in the Chillon Valley) [30]. The majority of such baskets are thought to be late pre-Hispanic; museum inventories frequently assume they date to the period in which the central coast of Peru came under Inca control in the fifteenth and sixteenth centuries, but they probably represent antecedent traditions, certainly dating back to the Middle Horizon [20, 25, 31].

The work of Dransart [19, 20, 25], Sillar and Hicks [26], and Tiballi [18] has highlighted the potential of pre-Columbian workbaskets and their contents to help understand textile production and to support the study of weaving technology and textile iconography. Through careful description, measurement and documentation of the tools and materials associated with a group of workbaskets drawn primarily from the BM and MQB collections, and by comparison with published data collated for other known examples, this study aims to determine whether:

1. Through identifying a pattern of contents that relates to a single textile tradition, a standard coastal textile production toolkit can be confirmed within the workbaskets, or if they reflect a variety of regional spinning and weaving traditions.

2. The spinning and weaving implements and other tools and materials stored in the workbaskets reflect everyday practice as a ‘working’ toolkit or were specially constituted burial offerings embodying other intentions.

3. A chaîne opératoire approach, including an evaluation of the presence and absence of materials, can shed light on textile technologies and the organization of textile production and provide potential evidence for state intervention.

4. Material from museum collections without a firm provenance and context can be used successfully in research and the potential use of detailed empirical analyses to improve the understanding of unprovenanced collections.

In this article a start is made in addressing these issues and findings are presented from the detailed analysis of the contents of 13 baskets and from a developing database of 336 further baskets in museum collections and publications.

Regional textile and spinning traditions

This analysis has been guided by evidence of different regional textile traditions and the observation that the choice of initial spin and final twist direction of yarns and threads tends to show regional and temporal continuities, with these preferences persisting among modern cultural groups [18; pp. 363–364, 32, 33]. Cotton (Gossypium barbadense) and camelid fibre, mainly from alpaca and llama (but possibly also guanaco or vicuña), served as the primary fibres used in Andean textile production [34]. Cotton was a local coastal resource, which grew in a variety of natural colours and was widely employed in coastal textiles [35]. While there is some archaeological evidence for the herding and breeding of llamas on the north coast [36], it is thought that most alpaca fibre is likely to have been imported from the highlands [37], although Late Intermediate period remains of domestic textile production at the site of Huayuri, Nazca, provide evidence of camelid pasturing and the use of some camelid fibre alongside predominantly cotton-based textile production [38]. However, recent work by Moulherat on south and central coast textiles suggests that alpaca was the predominant camelid fibre used, rather than llama, perhaps reinforcing the argument for the importation of camelid fibre from the highlands to the coast [39]. Moulherat’s results support conclusions drawn for south coast textiles on the basis of DNA analysis where the use of vicuña (Early/Middle Nasca periods) and then later alpaca/vicuña and llama/alpaca cross-breeds (Late Nasca) dominate [40].

In this contribution ‘spin’ is used to describe the initial direction in which raw fibres (hand processed and unspun) are manipulated and twisted to create yarn, with a twist to the right described as a Z-spin and a twist to the left an S-spin [32, 41]. Two or more single spun yarns may be plied by spinning together in the opposite direction. Where two yarns with an initial Z-spin are then plied by spinning together in an S-twist or S- ply, this is here described as an S(2z) construction following the terminology defined by Splitstoser, Figure 1 [42]. Note that it is sometimes impossible to determine the direction of the original or initial spin in archaeological threads but the final twist direction is always visible and is therefore capitalized. A single spin is documented as either S-spin or Z-spin.

While initial spin and final twist directions are not necessarily determined by the spinning technique used [32], in
The use of a supported spindle technique is associated with cotton spinning in coastal regions where the spindle may either be held horizontally (producing S-spun yarn) or vertically while one end rests in a vessel or on the ground (producing Z-spun yarn) [3, 11, 12, 33, 35, 45; p. 24, 47; p. 16, 48–50]. A spindle whorl is not necessarily required to keep the spindle rotating and spindles used in this tradition are generally short and slender [46]. During the Late Intermediate period, the north coast Chimu textile tradition was based on the use of unplied cotton yarns, normally S-spun, for the warps and wefts of plain-woven cotton textiles [11, 12, 15]. Chimu tapestry-woven textiles typically have S-spun and Z-plied cotton warps and camelid fibre or cotton wefts that are Z-spun and 2-plied S [11]. The archaeological evidence has been interpreted as suggesting strong central control of textile production at this period, with cotton being grown and processed locally [15]. Cotton spinning still survives in north coast regions today with the spindle being held horizontally, producing S-spun yarn [15]. While on the north coast an initial S-spin was typically utilized, on the south coast and in the highlands an initial Z-spin dominated [33, 47; p. 45, 48, 51]. However, it should be noted that there is unfortunately very little information available on south coast textile traditions during the Late Intermediate, the period of particular interest for this study [2, 12].

Where camelid fibres are associated with Late Intermediate period north coast textiles (e.g. at Chan Chan), these have been observed to be almost identical to camelid fibres in central coast textiles of the same date [44]. Rowe has suggested that the fact that these yarns are so uniform in appearance and that very few spindles associated with camelid fibre are found at coastal sites indicates that camelid fibre was being spun (Z-spun and 2-plied S) and dyed in the highlands, under centralized control, for export purposes [44]. Other researchers similarly suggest that skeins of camelid yarn were exported from the highlands to the coast [34, 37]. Although there are similarities in weaving techniques and iconography between north and central coast textiles at this period, there are also clear regional differences. For central coast textiles, all the yarns are typically S(2z) plied, although S- and Z-spun single yarns were also used in certain circumstances. Cotton was used in the warp of both plain-woven and tapestry-woven textiles, with either cotton or camelid fibres used in the weft [2, 11, 12]. During the Late Intermediate period, it has been suggested that textile production was less rigidly controlled in the central coastal regions than on the north coast [15]. Frame et al. compared the traditions of the two main central coast cultures during the Late Intermediate period, and stated that “Ychsms and Chancay spinners used a dual-purpose spindle that is pointed at both ends, which allowed them to spin Z-twist yarns when the spindle was oriented vertically and S-twist yarns when the spindle was oriented horizontally”, and both cultures showed a preference for using S(2z) plied wefts [14]. It was also noted that double-tapered spindles are not associated with the north coast tradition. Finally, they observed that Ychsm weavers tended to use cotton wefts while Chancay weavers generally used camelid fibre and that there were subtle differences in spinning practices. Interestingly, although Ychsm and Chancay ceramic styles differ, the spindles and spindle whorls used in the Chancay and Pachacamac spheres appear very similar [12, 18, 29].
Table 2. The workbaskets included in this empirical study

<table>
<thead>
<tr>
<th>Museum</th>
<th>Museum registration no.</th>
<th>Provenance, as indicated in the museum register</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Museum, London (BM)</td>
<td>Am1983.0.131</td>
<td>Casma, Peru</td>
</tr>
<tr>
<td>British Museum, London (BM)</td>
<td>Am1907.0319.175</td>
<td>Pacasmayo, Peru</td>
</tr>
<tr>
<td>British Museum, London (BM)</td>
<td>Am1907.0319.236</td>
<td>Pacasmayo, Peru</td>
</tr>
<tr>
<td>British Museum, London (BM)</td>
<td>Am1937.1011.25.a</td>
<td>Ancón, Peru</td>
</tr>
<tr>
<td>British Museum, London (BM)</td>
<td>Am1954.05.323</td>
<td>Peru</td>
</tr>
<tr>
<td>Pitt Rivers Museum, Oxford (PR)</td>
<td>1895.38.1</td>
<td>Ancón, Peru</td>
</tr>
<tr>
<td>Victoria &amp; Albert Museum, London (V&amp;A)</td>
<td>T312:1-1910</td>
<td>Casma, Peru / Early Colonial?</td>
</tr>
<tr>
<td>Musée du Quai Branly, Paris (MOB)</td>
<td>71.1878.2.834</td>
<td>Ancón, Peru / Late Intermediate</td>
</tr>
<tr>
<td>Musée du Quai Branly, Paris (MOB)</td>
<td>71.1887.131.14</td>
<td>Ancón, Peru</td>
</tr>
<tr>
<td>Musée du Quai Branly, Paris (MOB)</td>
<td>71.1887.131.15</td>
<td>Ancón, Peru</td>
</tr>
<tr>
<td>Musée du Quai Branly, Paris (MOB)</td>
<td>71.1932.108.368</td>
<td>Ancón, Peru</td>
</tr>
<tr>
<td>Musée du Quai Branly, Paris (MOB)</td>
<td>71.1932.108.370</td>
<td>Ancón, Peru</td>
</tr>
</tbody>
</table>

Methodology
To investigate coastal spinning and textile traditions through the study of the tools within workbaskets in the BM and MQB collections, a research methodology was designed both to assess the internal integrity of the contents of the workbaskets studied and to provide a large corpus of data to address the questions outlined in the introduction. The following approach was adopted:

1. Identification of as many known workbaskets as possible within the published literature or in (online) museum catalogues. Where the information is available, the provenance and contents are included within a database, using a standardized format that will allow future comparative analysis of the distribution and the range of basket contents;
2. To conduct detailed empirical analysis on the tools associated with 13 workbaskets to investigate the utilitarian functions and consistency of tools within and between these workbaskets;
3. To compare the results of the literature and catalogue review and the empirical study to determine if a ‘standardized set’ is found within most of the workbaskets, the outcome being used either to support or refute their internal integrity and whether one or more coastal textile traditions are represented.

Empirical analysis
An empirical study was undertaken on 798 archaeological artefacts from a group of 13 workbaskets drawn primarily from the BM and MQB collections, Table 2. With the exception of one basket (for which the longitude and latitude of the site are documented) these baskets have no secure archaeological provenance. This selection of baskets, with 10 distinct accession histories, potentially creates a sample from a more diverse range of chronological and geographical contexts than previously considered [18]. Building on Tiballi’s approach, a consistent recording system was developed for the analysis of the 13 workbaskets [18]. In order to assemble as much information as possible on the utilitarian and symbolic roles of the workbaskets, careful description and documentation was undertaken as described below, with the hope that other researchers may be able to utilize this approach in future comparative studies.

A complete inventory of the contents of the 13 workbaskets was compiled in a spreadsheet as the Inventory of workbasket contents. Simple counts were used to generate distribution and frequency data. Physical properties such as material, morphology, measurement, decoration, evidence of use-wear and thread spin were recorded in order to compare spinning and weaving instruments within and between baskets. In some instances there were multiple yarn specimens on the same spinning and weaving tools. With these objects, each yarn was examined and counted individually in order to contribute to data concerning fibre type, spin and fibre colour. All the artefacts were also photographed.

The material of all objects was identified, where possible, by visual analysis. In the case of fibres, cotton and camelid fibres were differentiated visually but no attempt was made to determine the camelid species used. Similarly, no attempt was made to identify specific plant materials, apart from cactus thorns. The shape of all tools and materials was described and used to create a standard nomenclature for spindles and spindle whorls, weaving needles and weaving sticks. Lengths and widths were measured for all complete tools in millimetres using a sewing tape measure or calipers as appropriate. Width was determined by measuring the widest part of an object. All the items were weighed using a small set of kitchen scales (1–50000 g) and composite items (e.g. a spindle with an attached spindle whorl) were not separated when weighed.

The surface treatment of tools was described by observing burnishing, painting, incising, stamping, pyro-engraving and carving. The colours used in the decoration of tools were noted by eye while the colours of the fibres were described using a Munsell 2.5BG–10RP and 2.5R–10G colour chart to aid colour comparison [52]. The Munsell colour system assigns colours labels based on their hue, value and chroma, allowing for a fairly objective comparison between shades. Evidence of use-wear on the tools — manifested in lustrous areas, dull or flattened tips on spindles and striations — was noted to detect possible functional roles. Where possible the thread spin (and ply) for all spun fibre was recorded, based on visual analysis. In this article, the terms yarn and thread are used interchangeably.
Dye analysis
The procedures developed for the analysis of the dyes associated with the fibres in the workbaskets (and then applied to the analysis of textile dyes as part of the ‘Andean Textiles’ project) were designed to preserve sensitive dye classes and key chemical markers, allowing conclusions to be drawn on the biological dye sources and dyeing technologies employed [53].

For analysis by high performance liquid chromatography (HPLC), a small sample of fibre (typically a few millimetres) was extracted in 30 μL of a 2:1 (v/v) mixture of dimethylformamide (DMF) and methanol at 100°C for five minutes; the extract was transferred to a HPLC vial. Next, 100 μL of a mixture of methanol, acetone, water and 0.5M oxalic acid in the ratio 30:30:40:1 (v/v), resulting in a final oxalic concentration of 0.05M, was added to the remaining fibre and the sample heated at 80°C for 15 minutes. This solution was then evaporated under nitrogen and the residue reconstituted with 30 μL of a 2:1 (v/v) mixture of water and methanol before adding this solution to the HPLC vial containing the DMF extract. The combined solution was analysed by HPLC by injecting 10 μL samples.

Analyses were carried out using an Agilent HPLC HP1100 system comprising a vacuum solvent degasser, a binary pump, an autosampler and a column oven. The column used for the separation was a Phenomenex Luna C18(2) 100 Å, 150 × 2.0 mm, 3 μm particle size, held at 40°C in a column oven. A HP1100 DAD detector was used with a 500 nL flow cell and monitoring wavelengths from 200 to 700 nm. Two solvents were used as eluents: (A) 99.9% water with 0.1% trifluoroacetic acid (v/v); and (B) 99.9% acetonitrile with 0.1% trifluoroacetic acid (v/v). The elution programme provided a linear increase in the ratio of A to B from 95:5 to 70:30 over a period of 25 minutes followed by a second linear gradient to 0:100 over the next 15 minutes. After eluting with pure B for 10 minutes, a third linear gradient was used to return to the initial composition (95% A to 5% B) in 15 minutes before eluting with this solvent mixture for a further 10 minutes to stabilize the system. The flow rate was fixed throughout at 0.2 mL per minute, creating a system back pressure of about 120 bars (12.0 MPa).

Results
A search of online museum catalogues and a literature review identified 349 baskets (i.e. another 301 baskets in addition to the 48 previously cited in the literature). The results are contained in the Workbasket database, which is too large to reproduce here.2 As only online museum catalogues were consulted, additional workbaskets will exist in other museum collections that have not been considered here.

Dransart identifies three general types of baskets: yarn-woven baskets generally called ‘cross-stick pack baskets’ [54; p. 271]; ‘split reed baskets’ [19]; and rectangular twill-woven workbaskets made of fibrous plant material plaited around wooden stiffeners [20, 25]. The majority of the workbaskets identified in this study are of this third type, Figure 2. Museum catalogues and databases provide at best only limited details on basket contents and generally list provenance from the central and north-central coasts of Peru, although there are also a few examples from the south and north coasts and the highlands. Time periods and cultures are rarely specified for the workbaskets but it seems clear that they originate from before the Late Horizon, with most labelled as being Late Intermediate or Late Horizon [25]. Museums often list workbasket dimensions; 10 of the 12 workbaskets from the Cemetery of the Sacrificed Women have lengths between 300 and 380 mm,
Table 3. Summary of the contents of the workbaskets included in this study

<table>
<thead>
<tr>
<th>Basket contents</th>
<th>BM Am1983.Q.131</th>
<th>BM Am1907.0319.175</th>
<th>BM Am1907.0319.236</th>
<th>BM Am1910.1010.31.a</th>
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<th>BM Am1954.05.323</th>
<th>V&amp;A T.3121.-1910</th>
<th>PR 1895.38.1</th>
<th>MQB 71.1878.2.834</th>
<th>MQB 71.1882.131.14</th>
<th>MQB 71.1882.131.15</th>
<th>MQB 71.1932.108.368</th>
<th>MQB 71.1932.108.370</th>
<th>No. of items</th>
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</thead>
<tbody>
<tr>
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<td>1</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>15</td>
<td>6</td>
<td>2</td>
<td>10</td>
<td>1</td>
<td>45</td>
<td>9</td>
<td>10</td>
<td>1</td>
<td>9</td>
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<tr>
<td>Battens / composite sticks</td>
<td></td>
<td></td>
<td>9</td>
<td></td>
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<td></td>
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Notes
a. A handwritten note associated with PR 1895.38.1 indicates that three combs, one spoon, 13 needles, one needle case and four wooden needles have been removed from the workbasket; b. Comprising 11 fibres; c. For the detailed study the figures were 0; 3; d. Set of 27; e. Seven included in detailed analysis; f. Comprising six fibres; g. Five sets; h. Eight included in detailed analysis; i. None included in detailed analysis; j. 11 sets; k. 30 included in detailed analysis; l. One has two whorls; m. 23 included in detailed analysis; n. One has two whorls; o. One has two whorls; p. One with whorl; q. All whorls (loose or associated with tools); r. 21 included in detailed analysis; s. 23 included in detailed analysis; t. Items representing 77 fibres.
widths between 140 and 220 mm and heights between 70 and 100 mm [18; p. 188]. Although potentially originating from far wider geographical and chronological contexts than the baskets listed by Tiballi, about 50% of the workbaskets in the Workbasket database for which measurements are available also fall within this size range.

Table 3 provides a summary overview of the contents of each of the 13 workbaskets selected for detailed empirical study and the frequency of occurrence of different items. The results presented below represent a compilation of data from the complete Inventory of workbasket contents that is too large to reproduce here.

Overall, the 13 workbaskets show similar trends in terms of their structure and content, and the range of materials associated with each workbasket closely mirrors those identified during the literature review and catalogue research. All 13 baskets are plaited workbaskets of rectangular shape with hinged lids and are fairly similar in appearance, although there are variations in the numbers of stiffeners and the interlacing arrangements. The two workbaskets recorded as originating from the north-central site of Pacasmayo (BM Am1907,0319.175 and BM Am1907,0319.236) appear very similar in form and content to the baskets reported from central coastal contexts, but the two baskets recorded as coming from the north coast site of Casma (BM Am1983,Q.131 and V&A T.312:1-1910) seem to be slightly larger in size than the others. The latter basket (from the Victoria and Albert Museum) is also possibly slightly later in date than the others examined (see below). Am1910,1010.31.a and Am1954,05.323 from the BM collection are perhaps the most distinctive of the group; the tools associated with BM Am1910,1010.31.a, from Acari on the south coast, appear to differ from the others and this basket contains fibres that exhibit an unusually wide range of colours (also seen in MQB 71.1887.131.15, which is unusual in having no associated tools). BM Am1954,05.323 was formerly part of the Wellcome Medical Historical Collection and, given the Wellcome Collection’s unique history, is unlikely to be an intact assemblage. BM Am1954,05.323 is anomalous as it appears to be associated with spindles that do not conform to a coastal tradition (see below), with three tools that will not fit in the basket at all and with two further tools that will only fit diagonally; it also contains whorls made of a very diverse range of materials by comparison with other baskets.

Of the various types of tools associated with the workbaskets, spindles are the most abundant and ubiquitous, appearing in 12 of the 13 baskets. Weaving sticks are the next most common item, occurring in nine of the baskets, followed by weaving needles found in seven baskets. Here the term ‘weaving stick’ is used to describe a number of cylindrical spinning or weaving implements where there are no obvious clues to their function, but these sticks may have been used as spindles, shed sticks, heddle rods, bobbins or shuttles, sewing needle cases or as weaving needles. As their function is not apparent, their measurements were omitted from the calculations for spindles and weaving needles. The weaving needles (also known as tapestry needles) are cylindrical implements with one end tapering to a sharp point and the other ending in a thicker point, often faceted. These tools frequently have painted or pyro-engraved lateral lines near the thicker point. They may have been used to pick up warp threads during weaving and appear to have been employed mainly as bobbins or shuttles for camelid fibre yarns, although similar-shaped tools have been used as drop spindles for cotton [18; p. 359, fig. 84]. Weaving battens, used to beat down the weft, occur in seven of the baskets. All the baskets also contain spun thread in various forms: as balls or skeins of yarn, on spindles, weaving needles, weaving sticks, sewing needles and winding rods, within textiles, and as parts of ornamental objects such as bracelets or rattles.

Because of the strong correlation between regional textile styles and yarn spin and fibre type and colour, particular attention was focused on the spindles, spindle whorls and fibres associated with the workbaskets. These materials and tools were selected as the most suitable to determine whether the workbaskets can be attributed to a single (coastal) textile tradition or represent distinct regional traditions, and because they would be most likely to provide insight into textile production. The detailed analysis of the spindles and spindle whorls, fibres and dyes is presented below. Where directly relevant comparative empirical data are available from other research, the results are presented alongside the new data in the relevant section.

**Spindles and spindle whorls**

Spindles are tools used to convert unspun fibre into spun thread or spun thread into plied thread. Clearly identifiable spindles (tapered wooden sticks with associated spindle whorls and thread) were examined first and served as models by which to identify other possible spindles that may lack such attachments. Other tools within the workbaskets that are not

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**Figure 3. Spindle whorl types:** (A) toroidal; (B) globular; (C) cylinder, (D)–(G) composite; (H) truncated discoid; (I) discoid (J) tapered barrel; and (K) barrel. Not drawn to scale

**Figure 4. Burnished spindle whorl BM Am1937,1011.10 (from BM Am1937,1011.25.a) with an incised and painted geometric snake and step motif sitting in the middle of painted bands on the spindle shaft**
identified here as spindles may still have been used as such (particularly weaving sticks).

In all, 353 spindles are associated with 12 of the workbaskets (MOB 71.1887.131.15 contains only fibre). The shapes of the spindles are remarkably consistent, with the majority having shafts that taper to points at both ends. The dimensions of the spindles are also similar, as can be seen in Table 4. For the spindles in this study, if they are considered per basket, then the average weight (when empty) is between 1.0 and 4.8 g, the average diameter between 2.6 and 4.7 mm and the average length between 198 and 317 mm. When all of the spindles are considered together, the overall average diameter and length are 4.1 and 269 mm respectively. Excluded from these calculations are four spindles from BM Am1954,05.323 that do not fit the pattern seen among other workbasket spindles. These four spindles taper only at one end and three hold larger spindle whorls that sit on the thickest end of the spindle. For the absolute dimensions of each spindle, see the complete Inventory of workbasket contents.

These spindle dimensions are also similar to those reported for double-tapered spindles from other central coastal sites. The 182 spindles from the Cemetery of the Sacrificed Women have an average diameter of 3.7 mm and an average length of 256 mm [18; p. 188], only slightly smaller than the overall averages for the spindles in this study. Four spindles from a Late Intermediate period workbasket (02.680) from the central coast that is in the collection of the Museum of Fine Arts, Boston, have similar dimensions, with lengths between 210 and 275 mm [2]. Similarly, lengths between 195 and 315 mm are reported for a group of Chancay spindles (dated 1200–1540) acquired by Robert Bliss before 1947 and now split between the collections at Dumbarton Oaks and the Textile Museum in Washington DC [12].

Spindle whorls are found in 12 workbaskets and of the 204 spindle whorls examined the majority are associated with spindles. Most of the whorls are ceramic although six of the baskets contain cylindrical whorls made of plant material and BM Am1954,05.323 also contains a few examples made of wood, stone, shell and copper alloy. For the ceramic whorls, nine different types or shapes are seen in the workbaskets (Figure 3), of which the tapered barrel shape (J) is the most common, occurring in 11 of the baskets. The whorls associated with the spindles acquired by Bliss show a similar range of shapes [12], as do those from two workaskets associated with a Late Horizon female mummy bundle from Ancón [28].

The different shapes of the whorls have little effect on their overall size or weight (Table 4) and would not affect their functionality. Their average height (averages calculated per workbasket) ranges between 10 and 17 mm. Diameters of the spindle whorls are also remarkably alike, averaging 12.8 mm when all whorls are considered together. Establishing the weights of the ceramic spindle whorls was more difficult as only six loose ceramic spindle whorls are present in the assemblages. The average weight of the loose spindle whorls is 1.3 g. Table 4 illustrates that there is little difference in overall weight for spindles with and without whorls suggesting 1.3 g is a likely average weight for all the ceramic spindle whorls. For the absolute dimensions of each spindle, see the complete Inventory of workbasket contents. These data are analogous to spindle whorls from the Cemetery of the Sacrificed Women, which have average heights of 15 mm, diameters of 12 mm, and weights of 1–4 g [18; p. 189].

Another interesting comparison is provided by the decorated spindle whorls found in various contexts (but not associated with workbaskets) from the earlier Middle Horizon occupation site at Pataraya, a highland Wari colony on a trade route between the south coast and the sierra in the Southern Nasca Valley [55]. Both cotton and camelid fibres are used in the textiles from the site and 98 decorated ceramic whorls of various shapes were recovered, averaging

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### Table 4. Spindle and whorl weights and sizes

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Notes
- Figures are averages per workbasket (except in final row). Baskets that do not contain complete spindles with whorls are noted as N/A.
- a. Spindle chipped but repaired in antiquity.

*Inventory of workbasket contents.*
2.2 g in weight, 9.3 mm in height and 15.7 mm in diameter. On the basis of the diameter of the hole in the whorls, the diameters of the spindles that would have been used are inferred to have varied between 2.6 and 3.7 mm (averaging 3.1 mm). As discussed later, this suggests that a supported vertical spindle was being used for spinning within this Wari colony, although this is a technique normally associated with coastal cotton spinning.

Perhaps the most obvious quality of the spindles and spindle whorls is their varied colourful and intricate decoration. Of the 327 spindles analysed, 186 are decorated; BM Am1910,1010.31.a is the only basket where the spindles lack decoration. It is likely that more spindles have painted decoration, but that it is concealed by yarn. Of the 186 decorated spindles, 178 are painted, with 165 having decoration slightly off-centre to the middle of the shaft in the form of simple bands around the tool. The other 13 spindles have decorations that cover the majority of the shaft, at times with curvilinear lines. Black, white and red, followed by yellow, are the dominant colours, usually appearing in combination. Again, these observations are similar to those for spindles from the Cemetery of the Sacrificed Women where 93 of 182 spindles are painted [18; p. 188] and for those associated with the Late Horizon female mummy bundle from Ancón [28]. The majority of the attached spindle whorls in this study sit on the spindle shaft slightly below centre; when the spindle has painted bands in this location, the whorl is always in the middle of the decoration, Figure 4.

While yarn covers the body of a few ceramic whorls and others are worn, all of those that are visible have a treated surface. The ceramic spindle whorls are burnished, painted, stamped or incised. The background on which decoration occurs is almost always a lustrous black, produced by a combination of smoking during the firing process followed by burnishing [20], and the most frequent decorative technique is a combination of burnishing, incising and painting with white, red and yellow pigment. The spindles and whorls are frequently coloured to create a matching set. Again BM Am1910,1010.31.a varies a little from the typical pattern and includes a set of almost identical unburnished truncated discoid whorls that are black in colour with orange, white, brown, yellow and red paint-filled incisions as well as plain spindle shafts, Figure 5.

The iconography on the spindle whorls embraces a variety of lines, dots and zoomorphic or geometric shapes. No correlation has been identified between iconography and ceramic spindle whorl shape. For the purposes of this study, the iconography is described based on what appears to be the main design on each whorl, using geometric terms (Figure 6) and influenced by literary sources on pre-Columbian textiles and ceramics [2, 18, 56]. The ‘eye’ (H) and ‘vertical lines’ (N) are the most common motifs across the baskets. Spindle whorls from other published workbaskets display very similar iconography. Specifically, 02.680 from the Boston Museum of Fine Arts has fish, step, eye, geometric snake and step, and stepped diamond motifs [2]. Basket 1919.13.25 from the Pitt Rivers Museum, Oxford, has a bird motif [20; p. 131, plate 4]. Tiballi’s illustrations of spindle whorl iconography show seven similar motifs (see examples b, d, f, g, j, k, r, t), while three of the spindle whorls (i, l, m) appear identical.
in morphology and iconography to whorls of this study [18; p. 190, fig. 24].

Of the tools examined, the spindles and weaving battens most clearly reveal evidence for use through lustrous, dull or flattened edges and tips. A total of 200 of the 326 spindles examined show recognizable signs of use-wear (Figure 7) and used spindles occur in all of the baskets containing spindles, although no basket contains only visibly used spindles. There is no physical evidence on the spindle shafts for the whorls being moved on and off the spindles, although removal of whorls from double-tapered spindles might leave no visible trace due to their morphology and also because the whorl hole diameter would be slightly larger than the spindle shaft. There are, however, spindles that lack any yarn or whorls, but are nonetheless wrapped with a small piece of unspun fibre. Spindles with attached whorls reveal that this unspun fibre was used to secure the whorl to the spindle shaft, and thus the unspun fibre associated with spindles may imply that a whorl has subsequently been removed.

Some of the tools show evidence of repair. Two spindles from BM Am1907,0319.236 and MQB 71.1932.108.368 have vertical splinters at the tips of their shafts reattached with thread, Figure 8. Similarly, a spindle whorl made of plant material in BM Am1907,0319.175 that split open vertically along its shaft has thread wrapped around the circumference of the whorl and shaft, securing the two together.

**Fibres and yarns**

A total of 451 spun and unspun fibre specimens in various forms, some associated with tools, were present within the workbaskets and were examined in detail. Textile and cord samples were excluded from this examination.

- Unspun fibre: five of the workbaskets (BM Am1907, 0319.175, BM Am1910,1010.31.a, PR 1895.38.1, MQB 71.1878.2.834 and MQB 71.1887.131.15) contain unspun fibre that has been hand processed. Of the 16 specimens present, seven are cotton cones (deseeded and hand-processed unspun cotton wrapped into a cone-like shape and tied with string), two are bundles of cotton and seven are bundles of camelid fibre. Six of the camelid samples were found in BM Am1910,1010.31.a, tangled in a bundle of vibrantly dyed threads, and the unspun specimens are likewise dyed. The weight of unspun fibre in the baskets ranges between 1.2 and 4.0 g.

- Spun yarn: the majority (96%) of the fibre associated with the workbaskets is spun, and a total of 166 camelid fibre and 269 cotton specimens were present. Of these, 131 cotton and 17 camelid fibre yarns are on spindles. Of the yarn specimens, 92% have an initial Z-spin: Figure 9 presents thread-spin and ply according to fibre type for the spun yarn in each workbasket. It is evident that camelid fibre yarn in the baskets almost exclusively has an initial Z-spin and that the majority of the yarn is plied (S(2z)). Only four of these camelid specimens have an initial S-spin: loose brown thread and a blue ball of yarn from BM Am1910,1010.31.a, and thread on winding rods from BM Am1983,Q.131. The majority of cotton yarns are spun in a single Z-spin although plying occurs at times. S-spun cotton specimens in the baskets exist on spindles, winding rods, weaving sticks and in one ball of yarn. Interestingly, nine matching spindles with white painted bands in BM Am1954,05.323 contain S-spun cotton thread, forming what appears to be a specific set. Camelid fibre yarn is most commonly found on weaving needles (28 specimens examined) as opposed to spindles. As noted previously, the weaving needles are all similar, tapering at one end to a sharp point and at the other to a thicker, often faceted, point, Figure 10. Generally they are painted or pyro-engraved with lateral lines or notches near the thicker tip.

- Fibre colour: using the Munsell Colour Chart [52], a total of 143 discrete colour matches for the threads and unspun fibres were made, representing both naturally coloured and dyed materials. It should be noted that due to degradation, the shades observed today might differ from the original colours, for example off-white fibre may originally have been white. Typically, the cotton associated with the workbaskets now ranges across shades of cream, tan and brown, but there are a few examples of red and blue shades and BM Am1954,05.323 even has samples of green cotton thread. While the red, blue and green shades are clearly dyed, the cotton seems to be largely undyed. In contrast, an array of shades exists for the camelid fibre specimens ranging from browns and golds through reds and purples to blues and greens. Overall, BM Am1910,1010.31.a and MQB 71.1887.131.15 contain the richest assortment of greens.
Table 5. Results of HPLC analysis of the dyes associated with camelid and cotton fibres in five workbaskets from the BM and MQB collections

<table>
<thead>
<tr>
<th>Collection</th>
<th>Yellow</th>
<th>Red</th>
<th>Brown</th>
<th>Tan</th>
<th>White/Undyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM Am1907,0319.175</td>
<td>Cameli: two samples dyed with a flavonoid-based dye rich in sugars containing kaempferol sugars, the aglycone and a quercetin sugar; one sample dyed with a flavonoid-based dye rich in quercitrin</td>
<td>Cameli: three samples dyed with cochineal</td>
<td>Cotton: no dye detected (nine samples); one sample contained cochineal</td>
<td>Cotton: five samples dyed with unknown tannin-based dye (series of polyphenolic components eluting around 21 minutes)</td>
<td></td>
</tr>
<tr>
<td>BM Am1910,1010.31.a</td>
<td>Cameli: one sample dyed with a flavonoid-based dye containing a luteolin monoglycoside and some quercetin. Four are dyed with a flavonoid-based dye containing a luteolin monoglycoside and a variety of quercetin (or quercetin-like) sugars and the aglycone. Two samples contain a similar range of flavonoids to those just described but also contain various kaempferol sugars and possibly the aglycone. One sample is dyed with a flavonoid-based dye containing chalcone components ($\lambda_{max} = 380$ nm) and a luteolin sugar</td>
<td>Cameli: one sample dyed with a mixture of a dye from a Bidens species and indigo</td>
<td>Cotton: no dye detected (four samples)</td>
<td>Cotton: indigo was the only dye detected in two samples; no dye detected in another four samples</td>
<td></td>
</tr>
<tr>
<td>MQB 71.1878.2.834</td>
<td>Cameli: one sample dyed with indigo (one containing a little cochineal)</td>
<td>Cameli: one sample contained only indigo while another three were dyed with a mixture of indigo and a flavonoid yellow containing quercetin and various quercetin and/or kaempferol-type flavonoid sugars</td>
<td>Cotton: one sample dyed with cochineal</td>
<td>Cotton: one sample dyed with cochineal and an unidentified dye; no dye detected in one other sample</td>
<td>Cotton: two samples analysed – no dye could be identified (chromatogram similar to white and tan samples in MQB 71.1932.108.370)</td>
</tr>
<tr>
<td>MQB 71.1932.108.368</td>
<td>Cameli: four samples dyed with cochineal and a little indigo</td>
<td>Cotton: one sample dyed with indigo</td>
<td>Cotton: two samples dyed with cochineal</td>
<td>Cotton: one sample dyed with cochineal</td>
<td>Cotton: two samples analysed – no dye could be identified (except a little indigo in one)</td>
</tr>
</tbody>
</table>
| MQB 71.1932.108.370 | Cameli: one sample dyed with a flavonoid-based yellow rich in a variety of flavonoid sugars including kaempferol sugars and a luteolin or apigenin-based sugar; one sample dyed with unknown non-flavonoid dye (series of UV-absorbing components which may indicate a tannin-based colourant) similar to that in MOB 71.1878.2.834 | Cameli: three samples dyed with cochineal | Cotton: one sample dyed with a mixture of Arrabidaea chica and a tannin dye (ellagic acid detected); no dye detected in six other samples | Cotton: two samples analysed – no dye could be identified (chromatogram similar to white and tan samples in MQB 71.1932.108.370) | Cotton: one sample dyed with a mixture of Arrabidaea chica and a tannin dye (ellagic acid detected); no dye detected in one other sample | Cotton: two samples dyed with cochineal | Cotton: one sample dyed with a mixture of cochineal and indigo | Cotton: four samples analysed – no dye could be identified (chromatogram similar to white samples) | Cotton: three samples analysed – no dye could be identified (chromatogram similar to white samples in MOB 71.1878.2.834) | Cotton: one sample dyed with a mixture of Arrabidaea chica and a tannin dye (ellagic acid detected); no dye detected in one other sample | Cotton: one sample dyed with a mixture of cochineal and indigo | Cotton: four samples analysed – no dye could be identified (chromatogram similar to white samples) | Cotton: three samples analysed – no dye could be identified (chromatogram similar to white samples in MOB 71.1878.2.834) | Cotton: one sample dyed with a mixture of Arrabidaea chica and a tannin dye (ellagic acid detected); no dye detected in one other sample | Cotton: one sample dyed with a mixture of cochineal and indigo | Cotton: four samples analysed – no dye could be identified (chromatogram similar to white samples) | Cotton: three samples analysed – no dye could be identified (chromatogram similar to white samples in MOB 71.1878.2.834) | Cotton: one sample dyed with a mixture of Arrabidaea chica and a tannin dye (ellagic acid detected); no dye detected in one other sample | Cotton: one sample dyed with a mixture of cochineal and indigo | Cotton: four samples analysed – no dye could be identified (chromatogram similar to white samples) | Cotton: three samples analysed – no dye could be identified (chromatogram similar to white samples in MOB 71.1878.2.834) | Cotton: one sample dyed with a mixture of Arrabidaea chica and a tannin dye (ellagic acid detected); no dye detected in one other sample | Cotton: one sample dyed with a mixture of cochineal and indigo | Cotton: four samples analysed – no dye could be identified (chromatogram similar to white samples) | Cotton: three samples analysed – no dye could be identified (chromatogram similar to white samples in MOB 71.1878.2.834) | Cotton: one sample dyed with a mixture of Arrabidaea chica and a tannin dye (ellagic acid detected); no dye detected in one other sample | Cotton: one sample dyed with a mixture of cochineal and indigo | Cotton: four samples analysed – no dye could be identified (chromatogram similar to white samples) | Cotton: three samples analysed – no dye could be identified (chromatogram similar to white samples in MOB 71.1878.2.834) | Cotton: one sample dyed with a mixture of Arrabidaea chica and a tannin dye (ellagic acid detected); no dye detected in one other sample | Cotton: one sample dyed with a mixture of cochineal and indigo | Cotton: four samples analysed – no dye could be identified (chromatogram similar to white samples) | Cotton: three samples analysed – no dye could be identified (chromatogram similar to white samples in MOB 71.1878.2.834) | Cotton: one sample dyed with a mixture of Arrabidaea chica and a tannin dye (ellagic acid detected); no dye detected in one other sample | Cotton: one sample dyed with a mixture of cochineal and indigo | Cotton: four samples analysed – no dye could be identified (chromatogram similar to white samples) | Cotton: three samples analysed – no dye could be identified (chromatogram similar to white samples in MOB 71.1878.2.834)
blues, purples, reds and oranges, while the other baskets generally contain brown, red, yellow and white fibres.

Dyes

Generally, the cotton specimens in the workbaskets appear in natural shades while the camelid fibre, in contrast, is dyed in a broad range of colours. More brightly coloured spun cotton is found in four of the workbaskets: a ball of faded red S(2e) thread in PR 1895.38.1, two balls of red S(2e) thread and a bundle of S(2e) blue thread in MQB 71.1878.2.834, four balls of blue S(2e) thread and four specimens of loose blue S(2e) threads in MQB 71.1887.131.15, and 17 weaving sticks with green Z-spun thread in BM Am1954,05,323.

HPLC analysis of the dyestuffs represented in five of the workbaskets (BM Am1907,0319.175, BM Am1910,1010.31.a, MQB 71.1878.2.834, MQB 71.1932.108.368 and MQB 71.1932.108.370) was undertaken and the results obtained are summarized here, Table 5 [57]. In total, 127 samples were examined. The cotton samples (54) appeared to be largely undyed, although some use of cochineal and indigo was noted and a number of the brown, tan and pale colours seem to have been obtained using tannin-based dyes and *Arrabidaea chica* [an orange-red anthocyanin dye] [58].

Of the more richly coloured camelid fibre samples (73), only one appeared to be undyed. A wide variety of shades seems to have been achieved using a quite limited range of dyes, suggesting that the colour obtained may have been modified through the use of mordants and by exploiting the natural colours of the camelid fibre. The range of dyes detected included cochineal, indigo and a limited range of flavonoid- and tannin-based dyes.

Discussion: originality of the assemblages

The analysis of the contents of the 13 workbaskets studied suggests that all generally contain a consistent range and distribution of tools and materials and, as discussed below, appear to correspond to coastal textile traditions, in agreement with their catalogued provenance. By considering a large number of tools from baskets that seem to have different provenance and collections histories, and by setting these results within a wider context through comparison with the data collated in the *Workbasket database*, confidence in the integrity of the assemblages and in the conclusions from this study is increased. However, while this study can link the tools, threads and workbaskets to general regions within the ancient Andes, it cannot prove that the assemblages inside each workbasket are completely original to that basket.

There is some evidence that may call into question the integrity of the assemblages, or at least affect the assessment of the frequency of occurrence of different tools and materials. For example, the contents of BM Am1910,1010.31.a are wrapped in a 1910 newspaper from Lima (Figure 5), indicating that these were removed at some stage but then replaced as they appear to be an intact assemblage. Documentation associated with PR 1895.38.1 suggests that some of the original contents have been removed and a note in the accessions register entry for BM Am1907,0319.236 indicates that its contents may derive from multiple burial grounds.

Finally, it was not possible to open BM Am1937,1011.25.a to examine its remaining contents due to the fragility of the basket itself; only those items that had been removed at an earlier date could be examined. In general, however, non-coastal materials do not appear to have been added to the workbaskets after excavation.

Discussion: textile production

The baskets appear to contain tools and materials deployed at different stages of textile production: raw/unspun fibre from which to spin; spindles and whorls for spinning; vessels on which to rest a supported spindle; spun yarns ready for weaving; and sewing needles for finishing or repair. In her work on the Cemetery of the Sacrificed Women, Tiballi uses a *chaîne opératoire* approach in order to better understand textile production processes and the organization of production “from raw material procurement through discard” [18]. Clearly the workbaskets studied here do not provide evidence for the entire process of textile manufacture, but they can potentially provide a snapshot of an individual’s tools and role in the process [18–20, 26]. Consideration of the tools and materials within such a framework underlies the discussion that follows and provides insights into raw material procurement, spinning and weaving practices as well as potential evidence for the organization of textile production and state intervention.

Fibres and spinning

The high proportion of cotton associated with the 13 workbaskets examined here strongly suggests that they conform to a coastal textile tradition. The majority of the threads have an initial Z-spin, following a highland or central or south coast pattern of spinning. A review of the threads by fibre type reveals that there are some examples of each spin direction among the cotton samples. The spun camelid fibre, on the other hand, is overwhelmingly uniform in its S(2e) spin. If, as the other evidence suggests, these assemblages are largely original and intact, the occasional presence of S-spun items on spindles suggests that both traditions of spinning may have been practised by the owners of the baskets, using the double-tapered spindles. Ethnographic evidence in the central Andes suggests that yarns spun in the opposite direction to the dominant local practice may have been produced for specific ritual functions [33, 59, 60]. Urton also suggests that the comparatively rare S-spin strings in Inca *khipus* were used to encode exceptional data, such as a narrative component that complements the use of more frequent Z-spin strings for most quantitative data [61]. The presence of S-spin items on spindles within workbaskets that show mostly a Z-spin tradition could have been intended to embody a special meaning or significance, possibly as a part of burial practice, or they could simply reflect north coast influence. One of the few examples of S-spin specimens in the assemblages is a set of nine spindles with cotton thread from BM Am1954,05,323. It is unclear whether the spindles were used to spin the cotton or if a special sample of S-spin threads was wrapped around the spindles. However, it is difficult to draw any firm conclusions since this workbasket may not represent an intact assemblage.

While the initial direction of thread spin suggests that the spindles were used vertically, detailed empirical study of the weights, dimensions and wear patterns of the workbasket...
tools is needed to determine more precisely how the spindles were being used. It is possible to use the drop spindle method with lightweight whorls; SPLITSTOSSER notes that spindle whorls weighing 6 g were used to spin cotton and camelid yarn at the site of Cerrillos in the Ica Valley [62], see also Mårtensson et al., who undertook experiments spinning wool using an 8 g whorl [63]. However, the extreme lightness of the ceramic spindle whorls examined here suggests that while they may have been used for cotton, they could not have been used to spin camelid fibre efficiently using this technique. The low weight of the whorls, combined with signs of use-wear on the tips of spindles, suggests that the majority of the spindles were supported in use. Spoons, shells, small gourds and wooden or ceramic vessels have often been reported in association with workbaskets and may have been used to support and steady the bottom of spindles when spinning yarn [20, 33]. Only one such vessel or ‘spinning bowl’ was noted in the baskets examined (V&A T.312:1-1910) but, due to dirt adhering to the inner wall of the gourd, it was not possible to look for evidence of wear. It is possible that such vessels were not always included in the burial context, that the items have become dissociated from the workbaskets over time or that the ground was being used to support the spindles.

Since a whorl is not necessarily required to keep the spindle in motion with this technique, the whorls may have been used to keep the thread from slipping during spinning [47; p. 19]. While there is little unspun cotton in the workbaskets, the numerous spindles with cotton threads and the evidence for spinning using a supported vertical spindle suggest that cotton was the primary fibre worked with the workbasket tools; it is of course possible that some coastal spinners used a supported vertical spindle to produce fine camelid threads. The four slightly larger and sturdier single-tapered spindles from the mixed assemblage contained in BM Am1954.05.325 may have been used within the drop spindle tradition for spinning camelid fibre and/or for plying [16, 59]; however, these spindles are an exception to those in all the other baskets.

The camelid yarns exist mostly as plied thread (S(2z)) in the form of skins or on weaving needles in the workbasket assemblages. The presence of S(2z) camelid yarn off a spindle represents a tertiary stage in camelid yarn production: in the primary stage the fibre is spun (unspun to single spun), in the secondary stage it is plied and finally it is removed from a spindle and either wound as a skin or wrapped around a weaving needle. The fact that the workbaskets generally lack these first two stages in camelid yarn production further suggests that the fibre was being spun elsewhere. It is also possible that spindles used to spin camelid fibre were not included in a coastal burial, but it is more likely that the lack of spindles with this material, along with the homogeneity of the camelid yarn spin and its ubiquity on weaving needles and in skins point strongly toward these coastal individuals obtaining the fibre pre-spun from either coastal areas that spun camelid fibre or the highlands. These conclusions are similar to those drawn from Late Intermediate period contexts at Pachacamac [18] and Huayuri, Nazca [38].

A number of authors have suggested that spindle and spindle whorl weights can provide information on the quality of fibre spun: the slighter the whorl, the finer the thread [33, 62; p. 368, 64–67]. TIBALLI places her spindles with ceramic whorls (with combined weights of 2–7 g [18; p. 358]) in the weight range for producing fine camelid fibre and cotton yarn [62; p. 368]. In this study, of the 10 baskets that contain complete double-tapered spindles with attached whorls, nine contain spindles with whors with combined weights of 2–5 g, certainly within the range for producing fine yarns. However, it is of interest to note that the length and thickness of the spindles appears more regular (standardized) than the size and weight of the spindle whorls. Regardless of the initial spindle whorl weight, as more spun thread is added to a spindle its weight and bulk will change but not the dimensions of its shaft. Thus it is possible that the spindle whorl’s minimal weight has limited effect other than to assist the initial spins needed to start the yarn. Indeed, six of the workbaskets contain spindles with cotton thread that seem to have been used without a whorl. It is more likely to be the dimension of the double-tapered spindle and technique of spinning rather than the whorl weight that will have the greater influence on the quality of the spun yarn [46]. If this is the case, the heavier spindles associated with the workbaskets may have produced a different quality yarn.

**Availability of raw materials**

The presence of some cotton fibre within the workbaskets shows that cotton was available in its unspun form, although in the absence of seeded specimens it is not possible to determine whether the cotton was being processed or was received deseeded by the owners of the baskets. The workbaskets do not contain any tools associated with the growing and processing of raw cotton, nor with the shearing and processing of camelid fibre. Although this could be used to argue that those using these baskets were not involved in the bulk processing of these materials, this may be an unwarranted assumption and it should also be noted that some of the coastal burial traditions from which these baskets may originate include a practice of incorporating raw cotton in the layers of the mummy bundles [14, 28].

As outlined in the ‘Regional textile and spinning traditions’ section above, there is evidence during the Late Intermediate period that spun and dyed camelid fibre for weaving was being exported from the highlands to the coast. The evidence from the unspun specimens within the workbaskets tends to support this conclusion; little unspun fibre of any type is found in the workbaskets and only two contain unspun camelid fibre specimens. Six of these specimens come from BM Am1910,1010.31.a, which interestingly contains the most fragile spindles seen in the workbasket assemblages with only one (BM Am1910,1010.31.d) showing any potential evidence for use. While there are numerous dyed camelid threads among the unspun bundles, it is obvious that the tools in BM Am1910,1010.31.a were not used to produce them. The other unspun camelid fibre is found in PR 1895.38.1, which also contains spun camelid threads but none associated with spindles.

With 90% of the thread associated with the spindles being cotton, there is little evidence for the spinning of camelid fibre. Unfortunately the few examples of camelid thread on spindles do not provide a clear picture as to how, and where, they were spun. Some of these spindles appear unused and the
yarn may simply have been wrapped around the shaft (e.g. spindle BM Am1910,1010.31.d from BM Am1910,1010.31.a), possibly for use as a shuttle or bobbin for weaving or, perhaps more likely, as a burial offering. Other spindles contain an insignificant amount (in terms of production) of fine camelid yarn such as one of the spindles (listed as item 42) in MQB 71.1932.108.368. Unlike the majority of camelid yarn within the workbasket, this yarn is a single Z-spin and on a spindle with a whorl, perhaps suggesting it was spun (or possibly re-spun) locally using a supported vertical spindle.

**Dyes and dyeing**

Based on visual observation, the range of colours associated with the fibres represented in the workbasket is broadly consistent with a central coast textile tradition, with threads in shades of brown, red, yellow and white, as seen in textiles from sites such as Ancón, Chancay and Pachacamac [68]. The brightly dyed colours of the fibres in BM Am1910,1010.31.a and MQB 71.1887.131.15 are perhaps less typical of central coast textiles. As noted previously, BM Am1910,1010.31.a is recorded as coming from Acari on the south coast and may represent a different regional sub-tradition.

Generally, the cotton specimens in the workbasket preserve their natural shades while camelid fibre, in contrast, is dyed in a broad range of colours. There is, unfortunately, little analytical data available relating to dye usage in Late Intermediate coastal textiles against which to compare the HPLC data obtained in this study of the workbasket. However, a group of Late Intermediate Central coast textiles from the BM was also analysed as part of the ‘Andean Textiles’ project and the dyes represented within the workbasket are broadly consistent with those seen in these roughly contemporaneous textiles [57]. This work, and analysis of a group of south coast textiles, is beginning to reveal cultural and chronological patterns in the choice of dyestuffs that may, in future, help to provide a temporal and regional context for the workbasket. The exclusive use of cochineal as a source of red dye for the fibres associated with the workbasket studied (rather than the use of plant sources of reds) may be a significant observation in this context [cf. 69-72]. The transition to the use of cochineal seems to occur from around the Wari period and by the Late Intermediate period only cochineal is seen in the reds.

Fibres may be dyed either before or after spinning; Cobo observed that fibre was dyed before spinning in Inca textile production [7; p. 223]. However, based on the evidence from the Cemetery of the Sacrificed Women, Tiballi suggests that here the camelid fibre was dyed as yarn rather than fibre [18], which is also a practice seen in some textile production by modern groups in the highlands around Cuzco [73] and in the Atacama region [74]. For the latter region there is also evidence of the same practice 3000 years earlier from the Tulán 54 site [74; p. 213].

In the present study, visual examination and HPLC analysis of the fibres suggest that the unspun cotton associated with the workbasket examined is not dyed, but the sample size is too small to permit definite conclusions to be drawn on the treatment of raw cotton fibre in coastal traditions. All six of the unspun camelid samples from BM Am1910,1010.31.a are dyed however, providing evidence that camelid fibre was dyed before spinning in this specific case. For the already spun and dyed yarns, it is not possible to specify when the dyeing was carried out and degradation of the fibres suggests that microscopic analysis of dye penetration may shed little light on this question. Other than in the use of indigo and cochineal, the dyes used for the cotton and the camelid fibres appear to show little overlap, possibly lending further support to the idea that the camelid fibres may have been dyed by highland dyers drawing on a slightly different dyeing tradition from coastal practice. When dyed, camelid fibre shows a vibrancy not matched in dyed cotton fibres. It is probably due to the relative ease with which camelid fibre may be mordanted and can take up dyes than many more colours are seen on camelid fibre specimens in the workbasket. However, dyes on cellulosic supports are often more fugitive than on proteinaceous supports. More extensive fading may explain why limited evidence of cotton dyeing was detected by HPLC analysis, thus affecting the conclusions that can be drawn.

Wherever and whenever the dyeing was taking place, a rich range of colours was achieved, apparently using a relatively limited number of biological and botanical colourant sources. This points to the skill of the dyers who were able to exercise a high degree of control over the outcome, presumably through knowledgeable selection of raw materials, mordants and dye combinations, and their choice of dyeing processes. Unfortunately, very limited information on dyeing technologies can be established from the literature, and there is no direct archaeological evidence, although plant and mineral remains associated with some archaeological sites (e.g. the necropolis of Ancón) may provide evidence of the raw materials available [38].

**Weaving, embroidery and sewing**

A range of tools connected with weaving, including weaving battens and sticks, is associated with the baskets. While the evidence presented in this paper suggests that the individuals who owned the workbasket were not spinning camelid fibre, the presence of camelid yarns in skeins and on weaving needles indicates that these individuals were likely to be responsible not only for spinning cotton, but also for producing textiles that incorporated both cotton and camelid yarns. Textiles produced using S(2z) spun cotton warps and S(2z) spun camelid wefts are typical of the central coast tradition, and particularly of the Chancay weaving tradition.

There are relatively few occurrences of sewing needles in the baskets, used for joining, finishing and embroidery. D’Harcourt suggests that the presence of containers holding unperforated cactus thorn needles within workbasket implies that needle eyes may have been worked as they were required [75; p. 9]. This suggests that there may not have been one needle that was repeatedly used throughout the weaver’s life, but a collection of potential needles, ready to be worked, used and perhaps thrown away or lost afterwards. The lack of cactus needles in workbasket may be because cactus spikes were plentiful and therefore disposable; this is different in the case of metal needles, however, such as the example found in the Early Colonial (?) workbasket V&A T312:1-1910.

**Tools: decoration and iconography**

Certain iconographic motifs are widespread across the Andes and include staff-bearing figures, felines, snakes and birds...
It is difficult to pinpoint whether the iconography seen on workbasket tools represents exclusively a coastal tradition (with the exception of a specific bird (pelican) motif seen in Figure 11, which occurs on many central coast Chimú and Chancay textiles and is akin to the profile-facing bird motif found on spindle whorls within the assemblages) [44]. As noted above, the choice of reds, yellow and whites to decorate the tools accords with the colours seen in central coastal textiles. The similarity of the finish of some of the burnished spindle whorls to fine blackware Chimu pottery has also been noted [20]. The workmanship seen on ceramic spindle whorls may be indicative of their importance, symbolic or otherwise, to the craft of fibre production and may also indicate the status of the individuals involved. This raises pertinent issues about how material culture expresses ideals and identity; as the spindle whorls are very small and would rapidly become covered in thread when in use, it is likely that they express something that is personal to the spinner. The repetition of certain motifs on spindle whorls across the different workbaskets links them in a similar cultural tradition and a more detailed analysis of this iconography might help to provide a temporal and regional context for these tools and, by inference, the workbaskets. However, as noted above, greater variations have been noted between ceramic styles than between spindle and whorl decoration, suggesting a rather broad tradition [12, 18, 29].

A further issue that needs to be considered is how the basket owners acquired their tools. In the specific case of the spindle whorls, analysis of the ceramics could potentially reveal if these were made by a number of different producers [76]. Many of the whorls seem to have been fired at low temperatures, with the incisions filled by paint that was applied after firing: the technology of whorl production deserves further study, but appears fairly simple and there is some archaeological evidence to suggest that they may have been made locally [38]. Others, with a more consistent form and decoration across several baskets, may have been mass produced by specific manufacturers and these, along with the baskets, could even have been supplied by those commissioning work.

The tools of BM Am1910,1010.31.a stand apart from the others analysed. The lack of burnishing of the ceramic whorls, together with a more limited iconographic repertoire consisting solely of the eye motif, diagonal, vertical and lateral lines, and X’s comprise a specific and distinctive set of matching tools. This basket is the only workbasket in the present study that has an association with human remains and with an exact findspot. Examination of the two associated mummies revealed a single spindle whorl, identical to those within the basket, among other accompanying objects. It is possible that this spindle whorl became separated from the workbasket or that it was once attached to a mummy bundle. Regardless, as a part of an identifiable set of spindle whorls, the object creates a stronger association between the mummies and the workbasket, offering the opportunity to link the study of the workbasket directly to specific individuals and their associated burial wrappings.

**Workbaskets as single consistent, utilitarian coastal textile production toolkits**

One of the aims of this study was to explore the potential for identifying one or more textile traditions by evaluating the selection of, and the technological processes represented by, the tools found in the workbaskets. Of the 13 baskets analysed here and drawn from a range of contexts, 11 showed marked similarities in the form of the basket, the tools, their wear patterns and the examples of thread found within them, suggesting that they were used by people with a shared tradition of textile working. The fibres and yarns within the workbaskets, and the high proportion of cotton to camelid fibre, provide the strongest evidence that the baskets conform to a coastal tradition. The spindles in the baskets are of the size and weight to spin lightweight and relatively fine fibre, probably cotton (which is plentiful on spindles), and the use-wear patterns suggest spinning using a supported vertical spindle, again all suggestive of a coastal textile tradition.

The predominance of initial Z-spin in the cotton yarns suggests a central or south coast influence, while the high proportion of S(2z) spun yarns and the tool decorations are perhaps indicative of a specifically central coastal textile tradition. The two baskets examined that are recorded as from the north coast site of Pacasmayo (BM Am1907,0319.175 and BM Am1907,0319.236) show identical patterns to the baskets reported from central coastal contexts. MQB 71.1887.131.15 contains no tools but here again the almost equal distribution of camelid and cotton yarn suggests a very similar textile tradition.

Two of the workbaskets studied stand out as exceptions: the mixed assemblage of materials in BM Am1954,05.323 from the Wellcome Collection, which has probably been altered since its excavation, and the small selection of tools in BM Am1910,1010.31.a with undecorated spindles and simply decorated whorls. If the provenance is secure, BM Am1910,1010.31.a comes from Acari on the south coast and, as noted earlier, it is possible that it represents a distinct coastal sub-tradition. Alternatively it may represent a different social and economic sector that produced distinct textiles. However, that these spindles show almost no evidence of use and had thread wrapped round them that had previously been spun on another spindle may suggest that the contents of this basket were specifically assembled by others and never actually used by the individual with whom it is associated.
The 13 workbaskets examined in detail appear to be reasonably representative when compared to the wider group of workbaskets recorded in the Workbasket database. These compiled data suggest that the practice of including workbaskets within a burial context was widespread, particularly along the central coast during the Late Intermediate period, and that the workbaskets are fairly consistent in size, manufacture and content. While the exact combinations of tools and materials associated with each basket differ, there is evidence for consistency in the contents and tool iconography that transcends local cultural traditions. Unfortunately, for the majority of the workbaskets in the Workbasket database, detailed analysis of the contents has not taken place and therefore it is not possible to draw conclusions on the textile traditions represented. In general there is a high proportion of cotton associated with the baskets and, where the contents have been analysed in detail, the results suggest that the majority of the workbaskets conform to a single coastal textile tradition. Where more detailed information is available, this suggests a central coastal textile tradition, although there is some variation.

The earliest examples of burials associated with workbaskets containing spinning and weaving equipment seem to be from north [77] and central [24; plate 16] coast sites and to date to the Late Moche (AD c.50–800) and Wari (AD c.650–800) periods respectively [20]. However these baskets are rather different in form to those typically found in central coastal contexts. This evidence suggests a long-lived tradition of including workbaskets in burials that continued throughout the Late Intermediate period and, under the Incas, into the Late Horizon and Early Colonial period. Although the majority of workbaskets are associated with sites on the central coast, workbaskets that are clearly part of a closely related tradition are also found at various north and south coast sites (and possibly in the highlands also). This suggests that the inclusion of workbaskets and tools within burials is a rather broad-ranging and persistent tradition spanning a large and culturally diverse region.

Signs of use-wear on spindles and evidence for the repair of tools underline the workbaskets’ utilitarian functions. Other researchers have also noted that some of the workbaskets show evidence for repair in antiquity including an example in the Pitt Rivers Museum collection (1941.2.115) [20]. Repair is positive proof of an object’s continued utility and value. This could be for pragmatic reasons, since it would be wasteful to discard a tool or object that could be repaired, or it could be a personal affinity for a treasured possession. Interestingly, one of the splintered spindles examined utilizes an S-spun thread to secure the splinter to the shaft, possibly suggesting selection of a yarn with ritual or protective qualities. The signs of wear and repair support the idea that these tools and baskets originally served a utilitarian function, providing further evidence that they represent a standard toolkit, although possibly modified later as it was repurposed for burial.

The presence of raw fibre may suggest that the workbaskets were used to store unspun fibre, but as Tiballi suggests for the workbaskets from the Cemetery of the Sacrificed Women: “the amount of raw fibre necessary to produce enough thread for a finished textile is exponentially larger than the amounts included in the weaver’s baskets” [18; p. 353]. There are various explanations for this: raw fibre may have been spun directly after processing and then either not retained for long or stored elsewhere. What is left in the baskets may therefore comprise the residue from larger amounts of fibre that were already spun; Bird suggests that workbaskets contain “residual ends” of cotton cones, saved as a base for the creation of future cones [33]. As the camelid fibre specimens in BM Am19/10,1010.31.a are already dyed it is improbable that they were being saved for future fibres to be added. If the raw fibre does indeed represent spinning residues, it is interesting to note that the threads produced are not preserved within the same workbasket, as none of the unspun dyed samples matched the dyed yarns (on the basis of the assigned Munsell shades). An alternative explanation is offered by Tiballi, who suggests that the unspun fibre was “sufficiently important to the process of textile production, and thereby to the identity of the weaver, that a token amount was included with the burial goods” [18; p. 353]. It is also possible that the majority of workbasket yarns may already have been incorporated into textiles or removed before burial, or that these short remnant threads were kept by weavers for potential use in repairs.

The marked similarities in form, materials, dimensions and decoration of the majority of the workbaskets and the specific tools they contained argue for a degree of standardization and may even suggest centralized production. This raises intriguing questions about control over their distribution and how they were supplied to the individuals who used them. Repeated motifs on the spindle whorls are executed in a very similar fashion in 11 of the baskets examined. Although not necessarily associated with workbaskets, Siveroni notes that well-made and finely decorated whorls are more common at certain periods such as the Nasca Middle Horizon [53] and Late Moche [46], which may point to differences in the status of weavers and thread makers and a change in the economic or social roles of cotton weavers between the Middle Horizon and the Late Prehispanic Period in the Nasca drainage [38]. Further, in light of the very similar whorls associated with high status *adilla* production at Pachacamac, the question might be asked as to whether this would have a bearing on the status of the workbasket owners. The fine quality and wide range of colours of the predominantly Z-spun yarn in the workbaskets is certainly consistent with the highest quality weavings found in Andean coastal regions from the Middle Horizon period onwards, suggesting that the owners of these baskets were highly skilled artisans involved in making textiles of superior quality. It is possible that some of the baskets were issued by the state or members of the elite commissioning textile production – this certainly could have been the case for the baskets and tools found at Pachacamac as the Inca state was required to provide workers with the raw materials and tools they needed to carry out state-sponsored production [18, 78].

**Utilitarian toolkits or burial offerings**

Other perspectives on the nature of workbaskets and their contents must also be addressed in the light of their role as burial offerings. The decision to include workbaskets as burial offerings must have been in part a response to the role and status of the deceased individual, the circumstances of his or her death and attendant community concerns, which need not imply that the individual involved was invariably associated with textile production in life [15]. The understanding
of death and the methods of burial varied in different periods and regions of the Andes, but ancestor veneration is a long-lived tradition in the central Andes and the iconography and burial practices of coastal regions from the Formative period onwards indicate that the dead were considered as active members of society even after their death [79]. This carries the implication that the ways in which the people engaged with the deceased at their burial would take into account their influence after death on the affairs of the living [80], involving power, warfare, production and health [81]. It is likely that objects found in mortuary contexts do not simply reflect the everyday life of the deceased, but were also a means of influencing the deceased’s continuing activities, decisions and powers after death.

There is clear evidence from the baskets and the spindles of use-wear and repair, indicating that workbaskets served practical utilitarian functions and were not made especially and specifically for purposes of burial. It seems reasonable to assume that the majority of workbaskets were indeed the personal possessions of the deceased. Nonetheless, the contents of the baskets must be considered dynamic in that materials may have been added or removed in preparation for burial. It is possible that the workbaskets were too intimately associated with the deceased to be kept and reused by the living and were thus chosen to accompany the deceased into burial. Another possibility is that in death the role of the deceased was redefined and the tools reflected the hopes and aspirations that the living had for the deceased’s future role as an ancestor in the community of the dead.

It is uncertain if the amounts of fibre and thread in the baskets are indicative of utilitarian function or of burial practices, as there could be practical reasons for their small volume, as noted above. Conversely, the yarns in the baskets may have been presented for burial and were not actually spun by the deceased. It is plausible that yarns with a range of fineness and spin direction were spun by relatives or other weavers in the community and placed in the baskets for use in the afterlife or as symbolic tokens of the spinning or weaving process [18]. A few baskets contain implements showing signs of use-wear that have been very carefully wrapped with thread, suggesting a deliberate preparation of utilitarian tools for a new role as burial offerings.

The number of spindles included in some baskets (assuming that these are original to the burial context) is also of interest [25]. Some baskets contain many more spindles than any one spinner could have used in life. Goodell’s fieldwork in 1967 in the southern highlands suggested that the number of spindles a spinner owned could vary but was never a single spindle [16]. The spindles may have been added prior to burial to keep the spinner supplied for eternity or placed as offerings so that the deceased would assist the living and share his or her knowledge from beyond the grave. Another possibility is that their presence may have indicated that the deceased was “sanctioned to distribute the spindles to other spinners” and “to control the spinning activities of others as she or he had done while alive” [25].

DeLeonardis and Lau suggest that special offerings such as hair and plant materials were included as grave offerings for the purpose of propitiation [81]. Items that are not expected in a utilitarian assemblage of tools (such as unworked shell, musical instruments, ornamental objects, leaves and agricultural specimens), and materials that would not have been readily available, such as colourful feathers and Spondylus shells that are native to modern coastal Ecuador [82], may fall into the category of specific grave offerings. While these objects could have performed utilitarian or ritual functions for the basket owners in life, they could also have been added to the baskets for distinct ritual purposes [83]. Such items are found in BM Am1983.Q.131, BM Am1907.0319.175, BM Am1910,1010.31.a, BM Am1954,05.323, PR 1893.38.1, V&A T.312:1-1910, MQB 71.1878.2.834 and MQB 71.1887.131.14. Of specific interest are the peanuts, maize and beans placed in the workbaskets, as these are crops common to the central coast [84]. Some of these items may also be important in dating of the workbaskets; for example, the beads found in V&A T.312:1-1910 may be of glass. Glass beads were only introduced to the Andes in the sixteenth century, suggesting that this workbasket is Early Colonial in date [85].

Future research
The ubiquity of workbaskets and their similar contents high-light spinning, weaving, and burial traditions along the Andean coast. Through the detailed empirical study of the tools and materials within a selection of baskets presented here, it has been possible to establish a methodology, baseline data and research avenues that can be pursued in the future. To explore the full range of information the workbaskets can offer and thus provide greater insight into textile technologies, dating and provenance of the workbaskets, the following topics could be addressed:

1. Empirical analysis: following the methodology presented here, further empirical documentation and analysis of the contents of workbaskets in other museum collections, as well as material from recent excavations, will help to create a larger data set against which the findings of this and other studies can be tested.

2. Settlement sites: these may yield archaeological evidence for workbaskets or debris from textile production (revealing local technologies such as spin direction and dyeing); their relationship with the material found in funerary contexts could be explored and they may also indicate whether more stages of textile production occurred within the domestic sphere. An example of this approach is Siveroni’s analysis of spindles, whorls, cotton and camelid fibre yarns, needles and weaving implements from domestic contexts in the Late Intermediate period site of Huayuri, Nazca [38].

3. Procurement of resources: the sources of the plant material used to create the workbaskets and associated tools might be studied and any chronological or regional differences that may provide clues to their provenance and manufacture investigated. The fibres used in the workbaskets are described in publications as various species of grasses but these have not been subject to scientific investigation [22; pp. 207–211, 23; p. 495, 24; vol. 3, plate 86, 30; p. 19, 86; p. 227]

4. Gender: the extent to which ownership of workbaskets is gender specific could be explored. Workbaskets associated with human remains, such as BM Am1910,1010.31.a,
may be investigated for further insight into the division of labour for specific stages in production.

5. Textiles: further research could focus on the textiles that may have been produced using the variety of thread found in the baskets. Rowe and Cohen state that yarn is spun according to the type of textile to be woven [60]. It might be possible to determine the purpose of the threads from the quality of spin, choice of dye or comparison with surviving fragments of cloth found within some workbaskets.

6. Iconography: the relationship between the iconography on spindle whorls and that on coastal textiles or ceramics could be investigated and the results potentially used to provide temporal and cultural context to the tools and baskets.

7. Dating: current evidence suggests that workbaskets were in use from the Middle Horizon to the Early Colonial period, but a campaign of radiocarbon dating of organic materials associated with the baskets and their contents could help to explore this further. Dating might answer questions about the contemporaneity of the assemblages and the degree to which changes in Wari or Inca state control influenced weaving activities on the coast.

8. Archival research: study of the collection histories and archival records in institutions holding workbaskets may provide insights into the development of early archaeological fieldwork in the Andes [26, 27]. Links between the workbaskets and other materials accessioned at the same time may help to shed light on provenance or other aspects of textile production.

Conclusions

Through systematic description, measurement and documentation of the tools and materials associated with a group of 13 workbaskets from museum collections and by comparison with data for other known examples, this study considers their role as both standard coastal utilitarian toolkits and funerary offerings. A database of 349 workbaskets and a detailed inventory of the 798 items in 13 baskets have been compiled. By considering a large number of tools from baskets with different provenance and collections history, and setting these into a wider context of other examples, confidence in the results obtained from the museum workbaskets is improved, notwithstanding the challenges of working with objects with limited contextual information. The majority of the 13 workbaskets examined appear to represent intact assemblages, largely unaltered since excavation. The data and results presented here suggest that the contents of the workbaskets do not represent the entire textile production sequence but can provide insights into an individual’s role at particular stages in the process.

The workbaskets examined are fairly consistent in size and manufacture. Further, while the exact combinations of tools and materials associated with each basket differ, there is evidence of a consistency in content and the associated artefacts – standardized slender double-tapered spindles with lightweight, highly decorated spindle whorls used for spinning fine (cotton) fibre – suggest that the majority of the workbaskets conform to a single coastal textile tradition, and perhaps more specifically, a central coastal textile tradition. The evidence of wear and repair supports the idea that these tools and baskets originally served a utilitarian function, suggesting that they represent a standard utilitarian toolkit rather than being specially constituted burial offerings. While the majority of workbaskets are associated with sites on the central coast dating from the Late Intermediate period, it appears that the inclusion of workbaskets containing spinning and weaving tools as burial offerings may be part of a longer lived tradition that continued, under the Incas, into the Late Horizon and Early Colonial periods. While predominantly representing a central coast textile tradition, the occurrence of workbaskets at sites along the whole of the Andean coast (and possibly in the highlands), suggests that they represent a rather broad-ranging practice spanning a large and culturally diverse region. While the workbaskets were initially utilitarian, their inclusion in funerary contexts also suggests a social, symbolic or personal significance extending beyond a solely utilitarian function. The modifications made to the contents of the workbaskets to serve as burial offerings have therefore also been considered within this study.

Study of the tools and materials associated with the workbaskets has also provided information on some of the different stages of spinning and weaving, the distribution of tasks, sources and flow of materials. The information obtained from spindles and threads and the evidence for spinning using a supported vertical spindle suggests that cotton was the primary fibre worked by the owners of the workbaskets, predominantly spun with an initial Z-spin. These individuals appear to have been responsible only for spinning cotton but also for producing textiles that incorporated both cotton and camelid yarns. It appears that the camelid fibre was not spun locally but was procured in a pre-spun (and likely pre-dyed) state either from coastal areas that spun camelid fibre or the highlands. Based on visual observation, the range of colours represented in the workbaskets is broadly consistent with a central coast tradition, with fibres in shades of brown, red, yellow and white, although a wider range of dyed yarns occurs in some workbaskets. HPLC dye analysis, undertaken to complement the empirical study of workbasket contents, suggests that the cotton is mostly undyed, making use of the available range of natural shades. However, more extensive fading might be expected with dyed cotton, perhaps meaning the evidence for dye usage is now lost. By contrast, the camelid fibre is dyed in a broad range of colours achieved using cochineal, indigo and a range of flavonoid- and tannin-based dyes. The rich variety of shades obtained suggests that the colours may have been modified through the use of mordants and by exploiting the natural colours of the camelid fibre, although again the impact of fading must also be considered.

The marked similarities in form and materials of the baskets and their associated tools raises intriguing questions about the degree of organization of textile production and state intervention, as well as the status of the individuals who owned and used the baskets. The study also highlights the research potential of materials drawn from museum collections: the results obtained in this study suggest that the possible lack of contextual data need not negate information obtained from analysis, and that artefacts without specific provenance can provide original and useful information, and should not be dismissed or neglected simply because of their accession history. This study was intentionally limited to an empirical and analytical investigation of spinning tools and dyes and
much still remains to be discovered from the workbaskets. A sound research methodology, a substantial body of comparative data and a number of future research avenues that may help to tie these objects to specific cultures, time periods and regions more closely have also been established. 

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References


Notes
1. It is planned to make the complete Inventory of workbasket contents available online. Alternatively, copies of the Inventory of workbasket contents can be requested from the authors.

2. It is planned to make the complete Workbasket database available online. Alternatively, copies of the Workbasket database can be requested from the authors.
SUMMARY

On 4 June 2014 the famous early Chinese painting, *Admonitions of the Instructress to the Court Ladies* (女史箴圖 *Nüshi zhen tu*; British Museum OA 1903,0408.0,1), was redisplayed at the British Museum in a new purpose-built case. This marked the end of a five-year period of investigation, consultation, conservation and rehousing of the handscroll, which had been accessioned by the Museum in 1903. This contribution surveys the painting’s treatment and housing history during the twentieth century, evaluating the circumstances under which the mount format was changed in the early twentieth century, the complexity of that procedure and the consequences for the scroll in the intervening years. It reports the steps taken to investigate its condition and prepare it for redisplay, and summarizes what has been learnt about its condition and history as a result.

Background

The *Admonitions of the Instructress to the Court Ladies* (女史箴圖 *Nüshi zhen tu*) or *Admonitions Scroll* is a silk painting in black ink and colour traditionally said to be after Gu Kaizhi (顧愷之, c.344–406), the celebrated master of figure painting. The scroll, which is approximately 250 mm high and 7850 mm long, is illustrated in Figure 1. Gu’s art is known today through copies of three handscrolls attributed to him, the originals of which have all long been lost. His fine linear, figurative style is reported in early written sources, while his painting technique is comparable to certain tomb paintings of the Jin dynasty period (c. 265–420) [1, 2]. The earliest seals and inscriptions on the painting in the British Museum come from no later than the eighth century and it is widely believed to be a copy of the lost original most likely dating from the fifth to the eighth century [2]. Exact copy painting has always enjoyed high status in China and it was fostered to preserve inherited works in perpetuity; masterpieces were replicated by the best artists and this remarkable copy has itself acquired the highest status on both the Chinese and world stages. Indeed, it has been argued that it is an inspired original work by an unidentified court artist [2, p. 8]. The *Admonitions Scroll* passed down through a succession of prominent connoisseur collectors, including the emperors Zhangzong (r. c.1190–1208) and Qianlong (r. c.1735–1796), each of whom characteristically added seals and inscriptions. The scroll was remounted several times and the Qianlong Emperor added to it an orchid painting of his own and a painting on paper of trees by the court artist Zou Yigui (1686–1772; British Museum OA 1903.0408.01.b). He housed the scroll in the Forbidden City in the specially built storehouse named Jingyi Xuan (Verandah of Delightful Serenity), part of the Jianfu Gong (Palace of Established Happiness), where it is supposed to have remained until the Boxer Rebellion in 1899–1901 [3]. The scroll passed into the possession of Captain Clarence Johnson (1870–1937) – exactly how remains a mystery – and eventually, on 8 April 1903, he sold it to the British Museum. An arson attack by eunuchs in 1922 destroyed the Jianfu Gong, but by then the masterpiece, after centuries of intimate private ownership, had entered the domain of a public museum with free access for all.

The painting illustrates a third century CE moralizing text written in verse by the poet and courtier Zhang Hua (張華, c.232–300). It consists of scenes illustrating rules of conduct through ideals of etiquette, each accompanied by the relevant
The scroll in the twentieth century

1903–1910s: condition

Captain Johnson apparently submitted the scroll to the Prints and Drawings Department in 1903 for an opinion on the jade tag then attached to it. It was inspected by the keeper of the department Sydney Colvin (1845–1927) and a curator Lawrence Binyon (1869–1943), who recognized that the painting was a masterpiece and ensured that it was subsequently purchased for the British Museum [4; p. 1].

The painting’s condition was always a matter of concern. Colvin wrote that “much worn and rotted, and bears many traces of ancient repair” [4; p. 2] and in 1904 Binyon referred to the overall brown colour of the painting: “a roll of brown silk, 9¾ in. wide, 11 ft 4½ in. long” [5; p. 40], as well as its general damaged state, with numerous signs of remounting and restoration. The latter, in his view, reflected the veneration and respect in which the painting had been held: “the extreme care which has been taken of the picture, the extraordinary skill devoted many times over to its repair – it has all been mended with a tact and cunning which no European could approach – both testifies to the veneration with which it has been preserved, and explains how so long a preservation has been possible” [5; p. 41]. Binyon also commented that one section in particular, a family group, was in very poor condition: “too damaged to yield much result from photography” [5; p. 42]. Indeed, three photographs in Binyon’s Burlington Magazine article show many repairs and losses that presumably exposed substantial areas of lighter coloured lining. This undyed silk lining still survives and its presence explains the extreme fragility described by Binyon and the risks that attend any handling of the scroll, see below.

In 1908 Binyon again described the scroll in his Painting in the Far East: “The condition of the silk, repaired many
times over with exquisite skill and care, shows that it is of high antiquity, and also that it has been most jealously preserved. It is a roll of brown silk, a little over eleven feet long, a little over nine inches wide” [6; p. 39]. Regarding pigments he wrote: “The figures are outlined with a brush in ink, the roundness of forms and folds of drapery suggested by light strokes of grey or red. Sometimes the spaces within the contours are left uncoloured, sometimes there is a tint of vermillion, either opaque or diluted. A tawny yellow, a dull green, and a mulberry purple have also been used; but these colours have sunk into the silk and lost much of their original value. The general effect is of a painting in black, grey, and vermilion red on a background of mellow brown” [6; pp. 41–42]. The scroll’s dilapidated condition was again described by Binyon in a report to the Museum’s Trustees in 1912 [7].

1910–1912: first public display

The first public display of the Admonitions Scroll in the British Museum was in the 1910 exhibition Chinese and Japanese Painting AD 500–1900 in the White Wing gallery of the Prints and Drawings Department [8]. This exhibition was not dismantled until 1912 since at that time a two-year display period was normal [9]. The exhibits were mostly drawn from the British Museum’s Anderson and Wegener collections together with Buddhist banner paintings from the Aurel Stein Collection. In 1911, as a result of the international attention that this exhibition attracted, and the interest in Asian art generated in London by the 1910 Japan-British Exhibition and the 1911 Festival of Empire at the Crystal Palace, the Trustees of the British Museum commissioned a printed facsimile of the scroll. They also decided that the fragile scroll should be cleaned and remounted.

1913: the printed facsimile

The woodblock-printed facsimile was commissioned from the London-based Japanese publishers Ohashi and produced in July 1913. In 1912, Mr Ohashi commissioned the Japanese draughtsman Sugizaki Hideaki (杉崎秀明: 1889–?) to make full-scale drawings and other specialists to cut the woodblocks, while Urushibara Mokuchū (漆原木虫: 1888–1953) (given name Urushibara Yoshijirō) was to print the 100 copies of the multiple-colour facsimile, Figure 2. Urushibara was paid to mount the replica prints in the format of a handscroll with colophons and a replica cover silk but without the other components referred to above. The colour replica reproduced the painting faithfully but did not record old repairs or damage. It was printed in sections from 34 woodblocks on very thin sheets of Japanese paper that were then joined with small overlaps and mounted as an imitation Chinese-style handscroll. In spring 1913 a machine was hired to blind print an impression of silk texture onto the mounted prints and an off-white paper strip was pasted around the mount edges, demonstrating the great attention paid to detail in copying the appearance of the original mount, elements of which still survive, for example the narrow paper turn-ins on the mount silk. The printed scroll replica was priced at seven guineas and sold together with an accompanying text written by Binyon [7].
The care taken with this replica provides an insight into technical aspects of the painting today, especially its colour, as Urushibara undoubtedly replicated the colours as closely as possible, including the background tone; comparison suggests that the painting has not become appreciably darker in the intervening years.

**Early twentieth-century mounting practice**

From the beginning of the twentieth century, as important acquisitions of Asian pictorial art increased, British Museum curators strove to acquaint themselves with the best methods for their care to complement the high standards of care and mounting that already existed for Western prints and drawings \[10\]. The Museum’s curators certainly faced a number of problems as scrolls sometimes arrived in poor condition and painted textiles came as chaotic groups of fragments that could be neither safely handled nor displayed. Outside expertise was needed, but, in general, scholarship in East Asian painting was still far from well developed, despite fashions and a growing aesthetic appreciation. What knowledge existed came from travellers, diplomats and dealers rather than the university or museum sectors. Scholarship from China was largely inaccessible, although contemporary American experts included some native Chinese and Japanese \[11\].

East Asian paintings are traditionally remounted periodically to help preserve them and the mount styles change with fashions, tastes and means. Mounts themselves remained unresearched from an aesthetic and technical perspective, or in terms of their provenance, until well into the late twentieth century, probably because they were rarely original to the work of art. To this day East Asian paintings are usually reproduced in publications without their mounts and with little related technical information. The study of historical mounting and framing is a recent development in both Asian and Western pictorial art and reflects advances in conservation and in the scientific study of objects to shed light on their provenance and on the history of collecting. In the nineteenth and twentieth centuries it was common for collectors across Europe and in America to discard old mounts, and many Asian paintings were glazed and framed in the manner of easel paintings or two-dimensional works of art on paper in the belief that a frame provided improved protection. Alternatively, scroll paintings were kept in their mounts but were applied to panels consisting of a wooden lattice core to which cushioning layers of paper had been attached. These flat-format mounted hanging scrolls remained unglazed and were easier to handle for Western curators.

In 1912 Binyon was given permission to travel to America for two months to study its rich collections of Chinese and Japanese pictorial art, particularly the collection of the Boston Museum of Fine Arts and “that of Mr. Freer at Detroit”. The former was described as “maintained under the expert

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**Figure 2. The Ohashi facsimile of the Admonitions Scroll, colour woodblock print by Sugizaki Hideaki and Urushibara Mokuchū with text (1913.7-8.01):** (a) the facsimile rolled in the manner of a Chinese-style handscroll and its box; (b) one of the 34 woodblocks (this block is for printing the black lines and accompanying calligraphy in parts of scenes four and five); and (c) section of the facsimile covered by the block in Figure 2b.
The advice of Mr. Okakura … probably the richest in the world and the best worth studying for the methods and appliances adopted for the safe keeping and exhibition of specimens” [12; p. 1]. At that time the preferred method for mounting East Asian paintings in American institutions seems to have been influenced by the Japanese practice of mounting folding screens in the Meiji period (ca. 1868–1912) using paper-lined wooden latticework supports described above.

1914–1923: scroll treatment
The treatment of the eight-metre-long Admonitions Scroll commenced in 1914. During this process the painting was separated from the colophons and inscriptions and the resultant divided handscroll was mounted flat in two sections. Two figures are associated with the project. First, Urushibara Mokuchū, who had trained as a woodblock printer in Japan, had come to London in 1908 in connection with the Japan-British Exhibition [13], and had subsequently remained to mount the facsimiles of the Admonitions Scroll described above. Urushibara was subsequently employed “to work on the repair and mounting of Oriental paintings” [14; p. 2], assisting Stanley Littlejohn (1876–1917) at the time of the “growth of the collections of Far Eastern Art” [14; p. 1], and he continued to work for the British Museum on commissioned projects to mount Japanese prints and Asian paintings until the 1920s.

The second figure is Littlejohn, who trained as an engraver, joined the British Museum in 1904 and was made head of the “repairing and restoring workshop in the Department of Prints and Drawings” in 1908 [15]; he was also described as a “restorer (prints and drawings and paintings) European and Oriental” [16]. Littlejohn had a particular interest in Oriental painting and was described in a Trustees’ report as “One of the most remarkable members of the staff … who has mastered enough of the language of the Japanese, and acquired enough of their confidence, to learn their technical secrets and apply them with a skill which no European, so far as is known, has
possessed before” [17; p. 6]. He had researched both the chemistry and symbolism of the pigments used in Chinese Buddhist painting and travelled to Brussels in 1913 to visit Raphael Petrucci (1872–1917), a leading expert on Chinese art, in connection with the reproduction of the Admonitions Scroll. In 1914 Petrucci came to London, engaged by the India Office to research the collection of Chinese and Tibetan paintings brought from Dunhuang by Sir Aurel Stein [18].

Before undertaking work on the Admonitions Scroll Littlejohn, perhaps working with Urushibara, had been entrusted with the treatment of the Stein Chinese silk paintings. A method was devised of backing the paintings with silk and mounting them on latticework cores made of cedar wood. A large number of Chinese paintings were mounted in 1911 for exhibition at the Festival of Empire at the Crystal Palace; Colvin wrote that “This work was carried out with great skill and success, and it is hoped that the Museum will ultimately benefit by the result” [19; p. 2].

Today, the mounts of these Stein paintings help to identify the materials and methods used in the subsequent mounting of the Admonitions Scroll. The Stein paintings were attached onto a lattice support, covered on the reverse with fine green cotton lined with kōzo paper, Figure 3. It appears that well before the treatment of the Admonitions Scroll was agreed, Littlejohn and Urushibara had successfully applied this method of mounting to East and South Asian scrolls and paintings, including some of the large-format fragmentary painted banners collected by Stein.

The remounting of the Admonitions Scroll coincided with the First World War. Littlejohn was killed in active combat in October 1917, soon after joining up, but by then the remounting work was probably mostly complete. In January 1918 Urushibara gave notice to concentrate on printmaking, but seems to have continued with commissions for the Museum into the 1920s as mentioned above.

No written records of the work on the Admonitions Scroll survive but the investigations carried out in 2014 led to the conclusion that the following steps were involved:

1. Disassembling the handscroll to separate the paintings, the colophons and the cover silk;
2. Replacing some of the paper linings but without removing the painting’s silk lining (see below);
3. Retouching losses of the silk;
4. Preparing a latticework panel by attaching paper underlayers;
5. Covering the latticework panel verso with a thin green cotton textile lined with kōzo paper;
6. Attaching the lined painting and colophons onto the two latticework panels respectively; and
7. Mounting with a ‘frame’ (jing pian 鏡片) format using plain beige Japanese silk borders and a narrow strip of mause inner mount, most likely applied after the painting had already been adhered to the panel, Figure 3f.

On 3 September 1923 the Admonitions Scroll is said to have been sized with cellulose acetate, as recommended by Dr Alexander Scott, then head of the British Museum research laboratory. This method had first been tested on sample objects and was subsequently used by Scott from 1920 on other painted silk and matt painted surfaces with apparent success [20, 21]. Judging by the presence of small individual fibre fragments sealed today onto the painting surface, the remounting in the 1910s had not resolved the issue of the brittleness of the scroll’s silk substrate or the tendency for fibres to continue to delaminate and break off. It was clearly thought that a radical consolidation method was required to stabilize the painting. Although details of this treatment were not recorded, it may have involved the application of a 2.5% (w/v) solution of cellulose acetate in acetone, as recorded in contemporaneous accounts [20, 21]. The cellulose acetate solution may have been brushed through a protective layer of tissue across the mount borders and the painting (for example, from the top to bottom edge of the mount), as both the painting and mount silk display similar lustre when inspected in raking light (see below).
1920s–1990s: scroll photography, display and mounting

The first photographic reproduction of the *Admonitions Scroll* probably dates to 1922. It was bound as a concertina album and is part of the Percival David Collection, which is now held at the British Museum. In 1925, Fukui Kichijirō of Sendai University and his students produced a different replica with detailed maps showing old damage. In 1966 a colour collotype facsimile was commissioned by the British Museum and produced by the famous Kyoto publishing firm Benrîdo (便利堂) in a close-fitting paulownia wood box with accompanying text by Basil Gray, the Keeper of Oriental Antiquities. It depicts small missing areas of silk substrate where the off-white lining is revealed (not present in Binyon’s 1904 illustrations) as well as darkening of the retouching medium applied in the 1910s to cover the losses seen in the 1904 photographs, Figure 4.

Records of objects on display (other than exhibition catalogues) began only in the second half of the twentieth century. When on display, the *Admonitions Scroll* would have been located in the Oriental gallery (now galleries 90 and 91). The painting was evacuated from London with other collections during the Second World War, but by the 1960s was on display in a vertical orientation in a purpose-built freestanding case. After the refurbishment of the Oriental gallery in the 1970s, the scroll was placed in a purpose-built wall case adjacent to room 91, with visitor-activated limited-time lighting. Throughout the 1980s and 1990s the scroll was in storage in the print room, boxed in a deep mahogany frame with hinged glazing, additionally protected by a second box and inspected periodically for signs of deterioration. By the late 1990s the painting and its mahogany frame were mounted vertically in a purpose-built wall case behind a blackout blind in a storage room shared with the Stein Collection, where researchers could study it by appointment.

Dedicated staff continued to be employed by the British Museum to carry out remedial work on East Asian material but it was only in the 1970s that conservators undertook studies of traditional East Asian formats and travelled to China and Japan. They also began to import Chinese materials and tools for the conservation of Chinese paintings. The first specialist Eastern Pictorial Art Conservation Studio equipped for scroll mounting treatments was established in 1983 with conservators trained in traditional East Asian methods, most notably Paul Wills. Jin Xian Qiu, who trained originally at the Shanghai Museum, joined the British Museum in 1987, introducing Chinese scroll mounting and training colleagues in traditional techniques. In 1994 the purpose-built Hirayama Studio was opened, providing a dedicated and fully equipped space for the treatment of East Asian scroll and screen paintings.2

Display and examination 2000–2010

Following an international colloquium *The Admonitions Scroll: Ideals of Etiquette, Art and Empire from Early China*, which was held on 18–20 June 2001 [1], it was decided to improve access to the scroll for the public. In 2004, a wall case was created that accommodated both storage and display. For three months each year the painting was on display under controlled light levels (c.50 lux) with concertina doors excluding light from the adjacent gallery outside these times. To avoid the risks of vibration from major building works, the painting was removed from this area to the Hirayama Studio in 2009. While the *Admonitions Scroll* was in the studio the opportunity was taken to undertake new investigations of its materials, structure and state of conservation.

Technical examination in 2009–2010

The published proceedings of the 2001 colloquium included a technical essay on the painting and a selection of images made under ultraviolet (UV), visible and infrared (IR) light [23]. A thorough technical examination followed in 2009–2010 to investigate and record the condition of the silk painting and assess its latticework mount. Initial examination was carried out in the Hirayama Studio in direct and raking light, and under magnification using a Leica M651 surgical microscope [24]. High-resolution imaging of the entire surface under UV, visible and IR light formed the basis for damage maps that were used to produce a full condition assessment [25]. Limited microsampling of non-original materials was undertaken to investigate the brown retouchings and the consolidant. The condition in 2009–2010 was also compared with evidence from archive photographs and the 1913 facsimile.

Technical imaging

Technical examination of the *Admonitions Scroll* included high-resolution, non-invasive and non-contact imaging [25]. To avoid moving the scroll from the conservation studio, a blackout ‘tent’ was created around the painting. Figure 5a. The painting was examined in eight sections and the images joined. For each section, a set of five images was acquired: under visible light (Figure 5b); with raking (low angle) light (Figure 5c); by reflected UV light (Figure 5d); UV-induced luminescence (Figure 5e); and with IR reflectography, Figure 5f. These images were used to generate multilayered digital damage maps that identified features highlighted by the specific imaging techniques and the differences between images acquired using the various techniques, Figure 5g. False-colour IR images were also produced to accentuate features that were not obvious in the visible images.

Visible light images showed the colour of the object and repair silks as well as the painting and retouching media. Raking light allowed the topography of the silk and painted surfaces to be recorded and was particularly useful in surveying delamination. UV-induced luminescence imaging was used to study the upper layers and very clearly showed silk damage, including fine fractures, splits and breaks. UV-reflected imaging revealed tidelines in the coating associated with areas of loss, possibly caused by consolidants, which were almost invisible in visible light. Finally, IR reflectography (using radiation in the range c.800–1700 nm, which penetrates the surface layers and can show underdrawings) revealed no underlying preparatory sketches, but provided an image in which the restorations and original painted features in the deteriorated and darkened areas, such as the animals in the scene of the mountain, were rendered more clearly.

Each imaging technique offered insights into repair techniques and helped with identifying the different silk batches that represented different remounting campaigns. For example, although closely matched, the repair silks show slight variations in hue, lightness and weave pattern. The repairs
Figure 5. Images made using various techniques during the technical examination in 2009–2010: (a) the blackout enclosure set up in the Hirayama Studio; (b) the first surviving scene in direct light; (c) a raking light image of the same scene; (d) image made in UV reflected radiation; (e) UV-induced visible luminescence image; (f) image made in IR reflected radiation (c.800–1700 nm); and (g) a damage map of the painting created using the information from the technical imaging.
seem to have been conducted using an ancient style known as *zhan dong* 斩洞 in which the repair and original silk are cut through from the recto to produce an exact fit. Generally, small repairs had been executed by cutting small square or angular shapes whose warp and weft threads aligned with the original silk. Larger repairs, for example those to the canopy of the palanquin, part of the mountain and the robes of many figures, had been made by cutting along design features such as the outlines of garments, which better concealed the repairs, particularly as the missing outlines and design had been repainted. These ink and bodycolour line and wash restorations were revealed clearly by IR reflectography.

The latticework support

The latticework core comprises a rectangular cedar wood frame measuring $c.425 \times 3740$ mm with one central horizontal crossbar and 11 regularly spaced vertical struts (as in Figure 3d); each element has a profile of $c.25 \times 17$ mm. The wood is exposed at one corner only, but the internal crossbar and struts can be located by applying gentle fingertip pressure along the mount perimeter. Although the painting is attached to the papered latticework and is therefore stretched, as is characteristic of East Asian screens, it seems that the tension is distributed uniformly between the recto and verso and parallel to the sides of the latticework frame. One issue is that, because the support is long and lightweight, there is a risk of bowing or twisting, which may cause the silk to fracture unless the latticework is stored and handled on a rigid support and protected from vibration.

The silk substrate

The *Admonitions Scroll* is some 1300 to 1500 years old and the fragility caused by age has been compounded by use, remounting treatments and environmental factors. The painting substrate consists of a continuous length of silk measuring $244 \times 3438$ mm, with the warp running horizontally. The silk has a fine, tightly woven, plain weave of $c.72$ warp ends (or 36 pairs of warps) and $35$ weft lats per centimetre, Figures 6a and 6b. As has been pointed out by Roderick Whitfield, Figure 6a shows an imperfection along the left side due to a break in the weft [26]. The silk has an overall brown tone that is attributable partly to ageing and partly to aged consolidants, facing adhesives, surface dirt and the coloured background wash that was traditional in Chinese painting (consisting of carbon black, iron oxide and gamboge in an animal glue binder) [27]. The silk still preserves a prominent ribbed weave structure and the textile threads resist the routine textile cohesion test of gentle tapping of the surface with a needle. However, as is evident from the type of damage observed, the silk is very brittle, which has been exacerbated by the failing adhesion to the first lining. Inspection of areas of loss showed that the painting was lined with a degummed plain, open-weave, off-white silk ($c.28$ warp ends and $28$ weft lats per centimetre; Figures 6c and 6d) with the warp oriented horizontally. Because both the lining and adhesive have become brittle – with the result that the fine ancient painting silk is now secured onto a relatively rough-textured support by a degraded adhesive – handling, vibration and changing environmental factors all encourage delamination. In 2010 the painting silk condition could be characterized as follows:

- Damage suffered prior to accession by the British Museum in 1903, for example numerous vertical, horizontal and diagonal cracks, fractures, losses and abrasions resulting from material decay through age and especially through handling, Figure 7a;

Figure 6. Details of the painting and lining silk of the *Admonitions Scroll*: (a) the painting silk showing the prominent weave; (b) a detail from Figure 6a at higher magnification; (c) the degummed lining silk with exposed silk filaments; and (d) a detail from Figure 6c at higher magnification.
Figure 7. Illustrations of the types of damage and restoration encountered on the painting silk during the examination in 2010: (a) cracks, fractures and losses, seen in raking light; (b) edge extension and repairs executed with matching silk; (c) repairs, both on areas of original silk and over some older repairs; (d) cupping with voids beneath, indicated by arrows; (e) post-1904 losses that expose the lining silk; (f) lifting areas (indicated by the arrow), square losses and zigzag cracks; and (g) loose fibres sealed onto the surface, indicated by the arrow.
• Extensive pre-1903 losses that had been filled with several types of silk repairs, including extensions to the top and bottom of the painting where the damaged edges had been cut off, Figures 7b and 7c. These repairs, which almost certainly date from not later than the Qianlong period (1736–1796) and possibly long before, were all produced using old, matching silk and had been executed with great skill;

• Small areas where adhesion to the lining had failed. These comprised detached fragments and silk threads that were prevalent at the perimeters of repair joins and near cracks or losses, and areas of ‘cupping’ where there was a void between the painting and lining silks, Figure 7d;

• Tiny post-1914 remounting losses; evident as small off-white areas where silk had delaminated and snapped off revealing the first lining, Figure 7e;

• Diagonal stepped or ‘zigzag’ cracks and square losses that are typical of a textile under tension, Figure 7f;

• Surface debris comprising fragments of silk thread, either original or repair silk, that were sealed onto the surface of the painting, probably following consolidation in 1923, Figure 7g.

As might be expected, the opening part of the painting shows more extensive repairs, as these scenes have suffered the most handling damage; as explained earlier, some sections from the beginning of the scroll (which are included in the paper copy in Beijing [2]) are probably missing entirely. The surviving scenes, especially the first, are testament to the abilities of previous generations of restorers.

It is notable that the large repair at the top right of the first surviving scene shows fewer fractures than the original silk and bears an impression of a collector’s seal from the Song dynasty (CE 960–1279) [28]. Some small repairs must postdate this phase of intervention as they are found both on areas of original silk and over the larger repairs, Figure 7c. These repairs were made from the recto and as they remain well aligned with the original, showing little sign of disturbance, it seems probable that the repairs and the silk lining itself are very old.

Damage maps show that the highest concentration of vertical and horizontal fractures in the silk is in the opening sections of the scroll, which were most affected by repeated rolling and unrolling as clearly indicated in Figure 5g, and in the final section, due to the narrow diameter of the roller. The horizontal fractures are located primarily halfway up the scroll and are distributed along its entire length in a pattern typical of the planar stress that results from the opening and closing of handscroll sections; horizontal fracturing may have been exacerbated by over-tightening of the scroll’s tying braid.

Pigments
The adhesion of the drawing and painting media to silk, a common concern with scroll paintings, did not appear to be an issue and the same was true of the retouchings, perhaps because the 1923 consolidation has served its purpose. The narrow range of colours described by Binyon in 1908 as already muted – black and grey ink, vermilion red, dull yellow and green, and mulberry purple – could still be observed. The retouched areas applied to the first lining in areas of loss had discoloured to a dark brown (see below).

1923 consolidant
Fourier transform infrared (FTIR) spectroscopic analysis of a fibre taken from the twentieth-century mount silk and samples of the retouching medium established the presence of cellulose acetate [24]. This consolidant may be responsible for the differential sheen and fine blanching revealed by raking light and evident in the UV-reflected images. Cellulose acetate is now known to become acidic and brittle on ageing, although in the case of the Admonitions Scroll the silk protein may have buffered this acidity. The cellulose acetate may, however, have affected the retouching medium referred to above.

Retouching media
The restored lines and washes on the Admonitions Scroll show clearly on the silk repairs in the IR false-colour images. They are further confirmed during examination under magnification.
as executed in black ink and red bodycolour. In contrast, the twentieth-century retouchings appear to have been applied directly onto the silk lining in the areas of loss. These are either black (e.g. in the calligraphy and on some of the figures) or a brown that presumably once imitated the background colour of the painting silk but, having now darkened, are very noticeable. The retouchings overlap the edges of the original silk, which creates the impression that the losses are greater than is the case, Figure 8.

Microscopic samples from the dark brown discoloured retouchings were analysed using Raman and FTIR spectroscopy and scanning electron microscopy with energy dispersive X-ray analysis (SEM-EDX) [24]. The retouchings contained vermilion, orpiment and some gypsum. Broadening of the peaks in the Raman spectra suggested that the orpiment had partially degraded to the white or colourless arsenolite (As$_2$O$_3$), probably as a result of light exposure. The darkening of the retouching therefore seems likely to be due largely to the darkening of the vermilion. The reactions that cause vermilion to darken are still the subject of active research and the mechanism is not fully established. There is a consensus that the presence of chloride ions and exposure to light will tend to promote these reactions [29–32]; chloride ions are sometimes found as impurities originating from vermilion production. SEM-EDX element
maps revealed a correlation between the distribution of chlorine and the location of the vermilion particles in the retouching material. Normally, darkening of vermilion represents a change to the outer surface of the pigment layer, but this is not the case here, where the retouchings seem to be uniformly discoloured; it is possible that the presence of cellulose acetate might have had an effect on the reaction. The acidic environment generated by the cellulose acetate, coupled with the presence of chloride ions, may have encouraged darkening. In contrast, the vermilion in the original painting and the pre-twentieth-century retouchings have retained their colour, perhaps because of a different source of vermilion, which may contain a lower concentration of chloride ions.

It has not been possible to establish the binding medium used in the retouchings. The presence of cellulose acetate has been confirmed but it was not in use as a binder when the retouching was carried out in the early twentieth century and it is unclear whether it is present as a local consolidant or a layer applied to the surface.

2013–2014: reconsideration and redisplay

The 2013 expert meeting

Following the 2009–2010 investigation, the British Museum’s Department of Asia and Department of Conservation and Scientific Research convened an expert meeting on the theme Early Chinese Silk Paintings: Best Practice in Storage, Conservation, Treatment and Display, held at the Museum on 24–25 July 2013. The participants included experienced East Asian paintings conservators, scrollmounters, scientists and art historians, Figure 9. The meeting covered both the treatment of historical Chinese silk paintings in general and the materials, condition and future requirements of the Admonitions Scroll in particular [33, 34], including plans for redisplaying the painting in a new case, consideration of the potential for future scientific investigation of the mount, silks and painting materials, and the options for future treatment.

The discussion of future treatment was based on a number of progressively more interventive options, each with an associated level of risk. These can be summarized as follows:

1. Rehouse only (no treatment);
2. As 1, but also consolidate and re-adhere areas that are lifting and, if possible, investigate and improve the appearance of the disfiguring brown retouchings;
3. As 2, but also detach the old mount and replace it with a better-constructed wooden latticework core covered with protective paper underlayers (a shitabari system) following contemporary best practice;
4. As 3, but also remove and replace the paper backings while leaving the silk lining;
5. Remount completely, including substituting the silk lining, keeping the painting in a flat format after treatment;
6. As 5, but mount the painting in a handscroll format.

After two days of discussion and detailed examination of the Admonitions Scroll there was unanimity among the attendees. It was considered that the painting had survived remarkably well
and that the twentieth-century mount was well executed. It was felt, therefore, that the minimally interventive options (1 and 2 above) represented the best approach to the conservation of the scroll for the foreseeable future. It was also agreed that it would be difficult to achieve the intermediate solutions outlined in options 3 and 4, so that if the painting was removed from its current mount, it would be necessary to undertake a full remounting either in a flat format (option 5) or as a handscroll (option 6). All those present believed that a full programme of research should be conducted before a responsible decision could be made regarding any course of interventive treatment, particularly those that involved the removal of the painting from its current mount. The general feeling was that, while it might not preserve the original appearance of the scroll, the current flat format had probably prevented the original silk from fracturing to a greater degree, particularly as it is lined onto a brittle silk with now-degraded paste and lining papers.

**Consolidation**

Following the expert meeting and in preparation for its redisplay, the *Admonitions Scroll* was treated in early 2014, mainly to consolidate the vulnerable delaminating areas and loose threads, as outlined in option 2 above, prior to its transport to the new case.

The consolidant was selected after lengthy discussion and testing to identify an appropriate type, quantity and method of application. It was considered essential that the consolidant would:

- Be compatible with the silk and media of the old scroll in terms of optical and structural change;
- Possess very good ageing properties that were compatible with the silk and other media, so that drying and long-term ageing would not produce local stresses or optical changes;
- Require the minimal use of moisture during application;
- Penetrate the tightly woven silk to ensure adhesion of the delaminated areas; and
- Have sufficient tack for quick and effective adhesion without the need to use weights.

To assess the choice of consolidant and the application method, five conservators independently carried out a sequence of tests on pieces of old and degraded painting silk. These tests, which included both traditional (starch pastes) and modern (cellulose ethers) materials, allowed the consolidants to be compared and discussed. The chosen consolidant, favoured by all those involved, was a mixture of a small amount of ‘gluten-free’ wheat starch paste with methylcellulose [35]. The wheat starch/methylcellulose option (along with several of the other potential consolidants) was also applied to samples of old silk, No. 1 Whatman paper and xuan paper so that they could be subjected to ageing tests [36]. The wheat starch/methylcellulose consolidant performed well, showing no optical change and remaining effective in securing fragile areas of silk.

The consolidant was next tested on a discreet area of the scroll itself, observing any effects under low magnification (×100 and ×160) using a Leica microscope with a 200 mm focal length to provide a longer working distance. By displaying the image from the microscope on an attached computer screen, it was possible for other members of the team to observe and comment on the method, until an agreed procedure was reached, Figure 10a.

The detached silk threads were obviously too brittle to risk placing weights on them or to insert a brush under lifting areas. In the ‘cupped’ areas, where the painting silk was lifting, there were no obvious voids through which to introduce consolidant. A range of methods was developed to address each problematic area. A long-bristled rigger brush dipped in consolidant was used; its tip was touched extremely lightly onto a point in, or adjacent to, the detached area and was held steady until the consolidant had been drawn into the silk, Figures 10b–10d. In the majority of cases the consolidant was allowed to cure without applying any pressure, Figure 10e. Where thread ends protruded while the adhesive was

![Figure 13. Schematic cross-sectional structure of the Admonitions Scroll lining papers, mount and latticework. Image: Paul Goodhead](image-url)
curing these were very gently touched with a dry flat brush to encourage adhesion and ensure correct alignment. A light-coloured brush was deliberately used in this procedure so that any transfer of colour onto the bristles would be apparent.

The consolidation was carried out under magnification as above and it was decided to apply the consolidant to all lifting threads, areas of cupping, voids, fractures and the borders of areas of loss. A grid was developed in order to ensure that the work was carried out systematically across the whole surface of the painting and frequent reference was made to high-resolution printed and digital images of the painting. The grid allowed 30 mm wide strips to be demarcated by protecting the adjacent areas with a soft, thin and smooth 12 g m⁻² non-woven polyester (Figure 10b) and offered a framework for recording the precise location of any intervention. Where necessary, depending on whether the consolidant was still readily absorbed, some areas of the scroll were consolidated twice or even three times.

**Brown retouching medium removal tests**

The feasibility of removing the twentieth-century brown retouching medium was also investigated. Given the brittleness of the lining silk, dry removal was considered unsafe. Tests showed, however, that following consolidation of the silk edges bordering areas of loss, the brown pigment within the losses offset readily onto soft medical tissue held gently in place with a fine dry brush after the area had been moistened with a tiny amount of a 1% solution of Methocel™ A400 (a low-viscosity cellulose ether). This method was tested successfully on an area of the background silk in scene two that is free of lines or wash (Figure 11) and it was concluded that, should a full treatment and remounting be attempted in the future, it is likely that this darkened retouching medium could be satisfactorily removed, or at least reduced.

**Latticework and mount structure investigation**

In spring 2014 the structure of the latticework panel and the lining of the *Admonitions Scroll* were investigated by carefully opening a small part of the green cotton layer on the verso of the painting’s latticework, having first tested this procedure on a mock-up. Two incisions were made, along the centre of two perpendicular wooden struts in the top half of the second latticework section, Figures 12a–12d. Samples taken from the paper layers that had been revealed were examined using the variable pressure scanning electron microscope (VP SEM).

The investigation demonstrated that the cotton textile is lined with kōzo paper that shows indentations made by a smoothing brush (*nazebake*). In the area that was examined there are approximately four layers of apparently good quality kōzo paper beneath the lined textile, Figure 13. The VP SEM examination of the shitabari kōzo paper showed a predominance of mulberry and cotton fibres, a few flax fibres, as well as abundant calcium oxalate crystals and other plant cell material, which attest to a lesser level of fibre refining during papermaking, Figure 14a. These paper layers appeared to be adhered to the wooden core in a fashion similar to the structure of a traditional Japanese screen (*shitabari*). Two of the paper layers were adhered together in the vicinity of the incision and also show smoothing brushmarks. It was not clear if they had been lined together overall or whether the adhesion between them was due to each layer being secured with adhesive only in the region of the struts. Beneath these layers a single sheet of kōzo paper had been ‘tipped’ onto the struts; this layer is slightly discoloured, particularly in the areas where adhesive was applied along the struts. On the recto of the latticework (immediately below the painting) there are four protective, cushioning underlayers of
kōzo paper tipped onto the struts and the lined painting is adhered/attached directly on top of these.

The lining of the painting consists of three paper layers adhered to the degummed silk lining. Working upwards, the final backing and the second lining are kōzo but of finer quality than the shitabari paper seen in Figure 14a. In the samples that were examined by VP SEM mulberry, cotton and flax fibres were also present but a higher level of refining was apparent, with fewer calcium oxalate crystals and non-fibre plant material, Figure 14b. These two layers are adhered to a thin, brown, short-fibred paper, composed mostly of cotton fibres that showed consistent fine damage cracks that are probably due to the age of the paper, Figure 14c. Such paper is referred to in Chinese as mian liao (棉料, cotton material), a term used for xuan paper that could be a mix of various plant fibres. The deteriorated condition of these fibres confirms that this lining must be quite old and that the twentieth-century remounting involved removing the original outer linings but stopped short...
of removing the lining silk and the first (brown) paper lining. The brown colour of this paper may indicate that it was dyed or may be a result of the paper type and its characteristics on ageing.

The incisions made in the cotton textile and shitabari papers in order to investigate the structure did not seem to cause undue stress and it was possible to realign and rejoin them easily using small strips of kozo paper and a minimal quantity of wheat starch paste. This implied that the structure was not overstretched or under excessive tension, and confirmed that the latticework mount had been remarkably well executed in the early twentieth century.

Redisplay

In June 2014 the Admonitions Scroll was redisplayed in a state-of-the-art display case as the central feature in a room that was designed for both long-term storage and periodic display (room 91), Figures 15a–15d. The large table case in which it is housed is manufactured in powder-coated steel and is divided by a wall to which interpretation panels and the lighting system are attached. The resulting double display space allows the painting to be shown on one side of the case and the colophons on the other. The display area is approximately four metres long and has two pedestals at each end within which are concealed the hydraulic lifting rams that raise and lower the glass cover. The stability of the 900 kg case structure helps minimize the risk of vibration to the object. The scroll and colophons are contained in rigid aluminium trays lined with neutral pH cotton mount board. The trays rest on the case floor, which is attached to a mechanism that allows it to be slid out safely (like a sturdy drawer) for close inspection, photography and study.

The glass case cover is angled at 45° to allow closer viewing and is constructed from 1.5 mm thick laminated OptiView™ glass. This is low-iron ‘clear’ glass with an anti-reflection coating to minimize reflections from the lights within the gallery. Two hand-drawn internal blinds are fitted so that the interior of the case can be blacked out completely when required. The blinds were designed and tested to ensure that no part can detach in a manner that would pose a risk to the scroll.

Although the environment in this gallery is controlled by air-conditioning and is relatively stable, a passive conditioning system using pre-conditioned Prosorb cassettes has been incorporated into a compartment on the underside of the case to provide additional buffering, particularly in the event of a temporary loss of normal gallery conditions. The temperature and relative humidity in the case are monitored using the radio telemetry system employed throughout the Museum.

All the materials and coatings used in the construction of the interior of the case were subjected to the Oddy test [37], but to ensure that any pollutants generated by the case or the materials of the scroll itself do not accumulate, MicroChamber® and pHoton™ papers are placed on the case floor and underside of the tray. In addition, a lead coupon has been placed inside the showcase to monitor the emission of organic acids.

Each side of the display case is equipped with two LED projectors that are housed remotely in the pedestal to avoid heating the compartment in which the scroll is located. Light is delivered from the projectors using a polymeric fibre-optic system. As the level of ambient light in the gallery is kept low and the scroll and colophons are surrounded by masks of a darker colour, the light levels on the painting can be maintained at around 40 lux while still allowing good viewing conditions.

The scroll will be on display to visitors for limited periods three to four times a year, within an annual allowance of 30 000 lux hours; the dates for display are advertised at the entrance to the gallery and on the Museum’s website. When not on display the internal blinds protect the painting from gallery light while information and images of the scroll are available from an interactive interpretation screen in the gallery.

Conclusions

For centuries during its complex history the Admonitions Scroll was kept rolled up and out of sight to all but its privileged owners. Following its accession by the British Museum in 1903 it became renowned as a major work of art worldwide. This prominence brought with it the responsibility to balance the safety and long-term survival of the painting with the need for public access and appreciation. In the 1910s the decision was made to mount the ancient, rolled handscroll as a flat painting, according to contemporary best practice, a decision that has proved beneficial given the brittleness of the painting and its silk lining. Subsequent examination with modern equipment has allowed the very complex problems the scroll raises to be highlighted for the first time, allowing a clearer understanding of its condition and a better assessment of the extent and possible sequence of treatment options. The meeting of experts considered these options and possible lines of future research on the Admonitions Scroll that might be pursued before implementing further practical treatments. The 2009–2010 and 2013–2014 examinations of the painting have been thoroughly recorded for future reference and comparison.

The redisplay of the Admonitions Scroll, which provides periodic display, multimedia information on the painting when it is covered and ready access for scholarly research, serves to balance the Museum’s responsibility to preserve and present this unique masterpiece.

Acknowledgements

The authors first shared and discussed their initial investigations during the meeting in July 2013 and wish to acknowledge the contributions and opinions by guest participants detailed in note 4. The authors are also grateful to Professor Roderick Whitfield for his careful reading and comments on this paper at various stages of editing, and particularly for his observations on the weave of the original silk contained in note 3. The redisplay of the Admonitions Scroll in 2014 was championed by Jan Stuart (then Keeper of the Department of Asia) and Clarissa von Spee and was made possible by substantial contributions from Huiyuan Wang, Tessa Keswick, Bruno Wang and Lily Jencks, and by the support of The Rothschild Foundation and Patricia Lennox-Boyd.

Project team

The investigations of the materials and structure of the Admonitions Scroll and the implementation of their findings during its treatment and rehousing have been a result of teamwork and cooperation by many members of staff at the British Museum over the past decade: conservators Jin Xian Qiu, Keisuke Sugiyama, Carol Weiss, Valentina Marabini, Monique Pullan, Sara Burdett and Joanna Kosek; scientists David Saunders, Catherine Higgitt, Janet Ambers, Caroline Cartwright, Valeria Ciocan, Joanne Dyer, Capucine Korenberg and Marta Melchiorre.
Materials and suppliers

- Methocel™ A400 low viscosity cellulose ether: Dow Wolff Cellulosics
- Xanthe Shrestha; and designer Paul Goodhead.

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Joanna Kosek (josek@thebritishmuseum.ac.uk), Jin Xian Qiu (conservation@thebritishmuseum.ac.uk) and Carol Weiss (cweiss@thebritishmuseum.ac.uk) are conservators and Janet Ambers (janammers@thebritishmuseum.ac.uk) and Caroline Cartwright (ccartwright@thebritishmuseum.ac.uk) are scientists, all in the Department of Conservation and Scientific Research at the British Museum. Keisuke Sugiyama (sugiyama.keisuke@aga.ua.ac.jp) was formerly a conservator in the Department of Conservation and Scientific Research at the British Museum and is now a lecturer at Tohoku University of Art and Design, Japan. Catherine Higgitt (catherine.higgitt@ng-london.org.uk) was formerly head of science in the Department of Conservation and Scientific Research at the British Museum and is now principal scientific officer at the National Gallery, London. David Saunders (@dsaunders-online.net) was formerly keeper of the Department of Conservation and Scientific Research at the British Museum.

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27. Van Gulik, R.H., Chinese pictorial art as viewed by the connoisseur, Istituto Italiano per il Medio ed Estremo Oriente, Rome (1938).
Notes

1. In 1975, Roderick Whitfield, Assistant Keeper in the Department of Oriental Antiquities at the British Museum and responsible for Chinese paintings, led a small group (the other members were Dr Norman Brommelle, Head of Conservation at the Victoria and Albert Museum, Peter Lawson, conservator at the British Library and Alf Crowley, conservator at the British Museum) for one month in China to study conservation practice and traditional mounting techniques in particular. In 1981 the British Museum engaged Paul Wills, who had trained since 1969 in the Usami Studio in Kyoto, and in 1986 Jin Xian Qiu, who had trained since 1972 at the Shanghai Museum; both were first introduced to the Museum by Professor Whitfield.

2. The Hirayama Studio is equipped with Chinese lacquer tables and large-format wooden drying boards, traditional furniture for Japanese scroll mounting and traditional East Asian tools and materials, acknowledging the importance of scroll mounting expertise in the British Museum. The setting up of the Studio is thanks to the generous support of Professor Ikuo Hirayama and the Five City Art Dealers Association of Japan.

3. The weaving imperfection along the left side on Figure 6a shows “a defect in the weft, where a weft has broken and the part above the break is missing, together with breaks in the warp ends; consequently the adjacent weft has moved to the left and split into two halves, on which the imprints of the missing warp ends are clearly visible. Because of the nature of silk the untwisted silk threads of the warp can be very long indeed; the whole warp has to be set up before weaving can begin. During the making of a warp one thread is gathered from each of a large number of spools on a frame at one side of a flat piece of ground and taken back and forth past two rows of pegs set some distance apart at either end of the space. Joints are made in the warp threads when a spool is emptied. When the bundle of threads has gone back and forth past all the pegs it can be transferred to the warping beam at the top of the loom. The process is repeated as many times as necessary to achieve the loom width (in the case of the Admonitions scroll, which is painted on silk 25 cm wide, this would be 25 × 72 = 1800 warp ends) ... the limitation on loom width imposed by the very nature of silk itself was responsible for the use of very long and narrow formats such as handscrolls and to some extent, hanging scrolls also”[26].

4. In addition to members of staff from the British Museum, the guest participants (in alphabetical order) were: Hyun Cheon (천주현), Department of Conservation, National Museum of Korea; Paul Garside, Department of Conservation, British Library; Chu Hao (褚昊), Department of Conservation, Shanghai Museum; Andrew Hare, Department of Conservation and Research, Freer Gallery of Art and Arthur M. Sackler Gallery; Sun-hsin Hung (洪順興), Department of Registration and Conservation, Taipei National Palace Museum; Masato Kato (加藤雅人), National Research Institute for Cultural Properties, Tokyo; Shane McCausland, Department of the History of Art and Archaeology, School of Oriental and African Studies, London; Iwataro-Yasuhiro Oka (岡岩太郎), Association for Conservation of National Treasures, Kyoto; Xiaomei Zhang (张晓梅), School of Archaeology and Museology, Peking University; Xuguang Zhang (张旭光), Department of Conservation, The Palace Museum, Beijing; Feng Zhao (赵峰), China National Silk Museum, Hangzhou; and Yang Zhou (周旸), China National Silk Museum, Hangzhou.

5. The construction of the shitabari has been improved over the course of the twentieth century to better protect paintings. In contemporary practice some eight underlayers of long-fibred and alkaline sheets of specialist papers, each of different function, are either tipped onto the latticework struts or applied onto the perimeter of the framework.

6. The team of conservators that investigated the consolidants and carried out the treatment comprised Jin Xian Qiu, Keisuke Sugiyama, Valentina Marabini, Carol Weiss and Joanna Kosek.

7. The consolidant mixture was prepared using ‘gluten-free’ wheat starch paste (WSP). According to the manufacturers, Nagata Sangyo Co. Ltd, the wheat starch powder consists of 99.3% starch, 0.4% protein and 0.3% ash, and is virtually gluten-free, although some traces remain. The paste used contained WSP (18% w/w before cooking or approximately 28–30% after cooking) and a 2% solution of methylcellulose (SUMCCL6625) in reverse osmosis water. The final solution comprised: 3% cooked WSP; 60% methylcellulose solution; and 37% water.

8. MicroChamber® paper is a cellulose paper that incorporates zeolitic molecular traps and an alkaline buffer, while pHoton™ paper is a high purity 100% alpha cellulose unsized and unbuffered storage paper.
A fresh assessment of a small stone plaque from China

Margaret Sax, Peter Hommel and Sascha Priewe

SUMMARY This contribution describes the analytical examination of a small stone trapezoidal plaque (1938,0524.400) in the British Museum collection. The plaque is poorly preserved: the reddish-brown and cream surfaces are damaged and much of the engraved design at the front has been lost. A total of 15 narrow circular perforations pierce the upper and lower edges and the carving was originally thought to be a jade component of a Chinese lute dating to the first millennium bc. However, studies of recently excavated finds from burials in central China by Jessica Rawson and Huang Tsue-me have allowed the British Museum artefact to be identified as part of a beaded headdress ornament. Further aspects of the material and origins of this plaque were investigated using a combination of Raman spectroscopy, optical microscopy and reflectance transformation imaging.

The finely banded material of the trapezoidal plaque was shown to be travertine, a variety of calcite. Originally, the stone appears to have been predominantly green with some grey areas. Although it was probably selected as a softer alternative to nephrite jade, the banding within the travertine was skilfully oriented to create attractive ‘watered silk’ patterns on the finished surfaces of the plaque. The current damaged state of the artefact is characteristic of weathering during an extended period of burial and the predominant reddish-brown colouration is largely due to the ritual use of powdered red cinnabar in burial. The study confirmed that the trapezoidal plaque (or tixingpai) formed part of a beaded headdress ornament made in China during the early first millennium. The style of engraving is typical of the Late Western Zhou and Early Eastern Zhou periods, indicating a date between c.850 and c.650 bc.

Introduction

A small, weathered trapezoidal plaque (1938,0524.400: Figure 1) was one of 273 Chinese jades purchased by the British Museum (BM) in 1937 from George Eumorfopoulos, an active collector of Asian antiquities during the 1920s and 1930s and a founder of the Oriental Ceramic Society [1]. The front face of this trapezoidal plaque bears the remains of an engraved curvilinear design. At the top of the plaque, six narrow perforations are formed by sets of interconnected holes drilled in the upper edge and the rear surface; nine perforations have similarly been worked along the longer base between the lower edge and the rear surface. At the time of purchase, this piece was thought to be part of a lute dating to the Zhou dynasty in China, 1046–221 bc. However, comparison with recently excavated material from central China and studies led by Jessica Rawson and Huang Tsue-me have allowed this small stone plaque to be placed in an entirely different context [2–11].

It is now clear that, following the Zhou conquest of the Shang in 1046 bc, a new fashion for brightly coloured beads – including red carnelian, blue faience and other stones and materials – grew among the Zhou and their allies. For several centuries, these beads were combined with plaques of jade, ivory and other materials to create an increasingly coherent set of complex composite costume ornaments that were buried with, and presumably had previously been worn by, both men and women of high social status [6]. One particular type of ornament found in female tombs comprises a perforated trapezoidal plaque (tixingpai) from which strings of beads were suspended. Some of these plaques are very similar to the BM plaque, which has been examined in the light of this new research and context.
Appearance and composition

Observations using an optical microscope confirmed that the trapezoidal plaque has been extensively damaged by weathering, probably during a prolonged period of burial. On the front of the plaque the engraved design can be seen preserved along the right side, but elsewhere the surface is pitted and degraded. The rear of the object is less extensively damaged and the original polish is preserved on about half of the surface.

Also apparent was the loss of original colouring. The front surface is predominantly cream to reddish-brown and grey, whereas the polished areas of the rear surface retain a greenish colour. Minute red deposits, which are preserved on many areas (Figure 1), were confirmed to be cinnabar – mercury (II) sulphide – by Raman spectroscopy. The ritual use of cinnabar in China has a long tradition and has been confirmed in burials of the late Shang and Zhou periods [12]. The current overall reddish-brown colouring of the plaque appears to have been imparted by powdered red cinnabar during burial. What remains of the colour of the rear face suggests that the stone was originally green with some grey areas.

At the time of its purchase by the BM, the trapezoidal plaque was described as jade, but the mineral of which the stone is comprised has now been identified as calcite by Raman spectroscopy. The material is finely banded and the colouring and opacity of the bands vary, characteristics that indicate the stone to be travertine, a variety of calcite. Travertine is formed by the dissolution of calcium carbonate in ground water and subsequent deposition by rivers, natural springs or geysers.

Confusion arises over the term for jade (yu) in China. It may be used in a narrow sense to refer to nephrite, the variety of ‘true jade’ usually worked in ancient China, or jadeite, added to the material repertoire from the mid-eighteenth century. However, yu traditionally means ‘beautiful stone’ and the term yu or yu shi (jade stone) is often applied broadly to describe carvings of other rocks or minerals such as quartz, serpentine and calcite. Following the nomenclature recently adopted in China to differentiate between true jade and its imitators, the term ‘calcite jade’ is appropriate for the material of the BM plaque [13].

Unfortunately, calcite is readily soluble in acids and the extensive loss of polish and damage to the surface and underlying layers of the plaque are consistent with weathering during an extended period of burial in a wet, slightly acidic environment. Furthermore, the finely banded characteristics of the travertine are likely to have facilitated the penetration of acid solutions between layers at the surface, rendering the carving particularly vulnerable to weathering.

Calcareous stones have a hardness (H) of three on Mohs’ scale; they are considerably softer and also less tough than nephrite (H of 6.0–6.5). Although the raw material for the trapezoidal plaque may have been selected as a softer alternative to nephrite, nephrite is usually relatively plain coloured and a factor governing the choice of travertine may have been its banding. The fine bands form undulating layers, which appear to have been oriented deliberately to produce attractive ‘watered silk’ patterns on the finished front and rear surfaces of the carving. About 12 fine bands lie within the plaque. At the centre, they are more or less parallel to the two principal faces and little patterning is seen. Elsewhere, the bands are oriented obliquely and variations between the colour and opacity of adjacent bands would have been highlighted.

Figure 1. Images of the weathered trapezoidal stone plaque 1938,0524.400 (81 mm high and 9 mm thick) showing: (a) the front surface; and, (b) the rear surface

Figure 2. Photomicrograph showing details of the watered silk pattern preserved in the polished surface at the rear of the trapezoidal plaque
A fresh assessment of a small stone plaque from China

The remains of the engraving on the more damaged front surface were recorded using reflectance transformation imaging (RTI), as described in the experimental appendix. With the help of the images produced using this technique, sufficient features were made visible to allow the design to be evaluated. Images rendered using different settings in the RTI viewing software show a symmetrical design of hooks and spirals in three registers, Figures 3a–3c.

**Attribution**

The shape and dimensions of the BM plaque closely resemble those of *tixingpai* that, when found in context in elite female burials in central China, form the defining component of a distinctive type of elaborate beaded ornament. These remarkable artefacts date from the latter part of the Early Western Zhou period (c.950 BC) to the Early Eastern Zhou period (c.650 BC) [6, 8, 11]. By analogy with excavated examples, nine strings of beads made of various materials would have been suspended from the perforations along the base of the BM *tixingpai*, hanging down as a dense tassel; different bead materials may have been ordered within the strings to create bold horizontal bands of colour. A smaller number of beads was probably strung together and threaded through the six perforations along the upper edge for suspension. The example illustrated in Figure 4 was excavated from tomb M31 at the Jin Marquis cemetery, near Beizhao, Shanxi province [2, 14; p. 95]. This set is dated to c.800 BC and composed of nine strings of red carnelian, blue faience and grey-green steatite or pyrophyllite beads attached to a nephrite *tixingpai*. Plaques of ivory, sometimes inlaid with turquoise, are typical of graves predating the mid-ninth century BC; thereafter nephrite and other visually similar stones appear to have become the materials of choice.

The design of hooks and spirals engraved in the BM plaque (Figure 3) is comparable with those of several nephrite *tixingpai* dating from the late Western Zhou and early Eastern Zhou dynasties, c.850–c.650 BC, and exemplified by decorated plaques recovered from tombs M31 and M102 at the Jin Marquis cemetery and tomb M27 at Liangdaicun, near Hancheng, Shanxi province, Figure 4 [6, 14; pp. 95 and 137]. Although complex beaded arrangements have been found in the graves of both men and women, the tasselled sets formed around *tixingpai* were associated exclusively with women. They are usually found in pairs running down from the area of the head and neck across the torso, and were probably originally attached to opposite sides of a headdress that has long since decayed. Unlike some elaborate beaded arrangements, *tixingpai* sets have no obvious heritage in China and their origin has been linked with the pastoral world of the Eurasian Steppe [6, 8, 15]. Structurally similar artefacts, identified as plait ornaments, that comprised metal and faience beads and pendants have been found widely in the graves of Late Bronze Age communities of the second millennium BC, and elaborate female headdresses continued to be an important feature of many later Eurasian pastoral societies [16, 17].
Conclusions
The results of analysis and examination showed that the perforated trapezoidal plaque in the BM was worked in travertine, a variety of calcite. The finely banded calcareous stone was originally predominantly green in colour, the banding skillfully oriented to create attractive watered silk patterns on the polished surfaces of the carving. The present damaged condition of the plaque is consistent with degradation in a slightly acidic burial environment, although the reddish-brown surface discolouration appears to be largely due to the ritual use of powdered red cinnabar in burial.

Based on comparison with excavated examples, this tixingpai was confidently re-identified as part of an elaborated beaded headaddress ornament of a type widespread in central China during the early first millennium BC [6]. These ornaments were associated with high-status women and were usually worn in pairs, hanging down from opposite sides of the head as flowing tassels of coloured beads. The style of engraving seen on the BM tixingpai is consistent with a date within the Late Western Zhou or Early Eastern Zhou periods, c.650–c.630 BC. This study also allows the carving to be placed in a broader context as part of the evidence for extensive cross-cultural contact between China and its neighbours.

Experimental appendix

Raman spectroscopy
A Dilor Infinity Raman spectrometer was used to identify the material of the plaque and the superficial red deposit. Measurements were made directly on the samples with a green (532 nm) laser with maximum power of ≤2.0 mW at the sample and an internal beam path. Spectra were collected for 5–20 seconds, with at least five scans used to produce each spectrum; they were identified by comparison with reference spectra from an in-house database.

Optical microscopy
Examination was carried out using a Leica MZ APO optical microscope at magnifications of ×8 to ×40 and images were acquired with Leica Application Suite V4.2 software.

Reflectance transformation imaging
The RTI images were made using a custom-built dome manufactured by the Department of Electronics and Computer Science at the University of Southampton [18]. A series of images of the stone plaque was made using the Nikon D800 camera fitted to the top of the dome. In each image one of the 76 LED lamps distributed across the inner surface of the dome was illuminated. This series of images was built into a composite RTI image using the software provided with the dome. The RTI image was viewed using the ‘RTIViewer’ software downloaded from Cultural Heritage Imaging [19]. Views that show particular features of the engraving to good effect were rendered from the RTI file, saved as two-dimensional images, and are illustrated in Figures 3a–3c.

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