Jewellery of a young Egyptian girl: Middle Kingdom goldwork from Haraga tomb 72

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ABSTRACT: Excavation of an intact burial at Haraga, Egypt (12th Dynasty) revealed the unusual presence of several gold catfish and tilapia pendants and gold bead necklaces, now in the collection of National Museums Scotland (NMS). Analysis of the pendants and gold beads by XRF and PIXE/PIGE has shown that the majority were made from silver-rich electrum with quantities of silver between 20wt% and 40wt%. Only the most skilfully crafted fish pendant was made with a high-purity gold alloy containing less than 7wt% silver. The gold beads, which were made by rolling foils of different thicknesses on a lime plaster core, are highly degraded. FEG-SEM observation of one corroded fragment revealed a porous texture of the surface corresponding to a failed annealing that caused an increase of the corrosion rate. The surface of the beads has a red coloration caused by the formation of gold-silver-sulphur compounds, characteristic of atmospheric corrosion of gold-based alloys.

Introduction

The site at Haraga consists of cemeteries in an area between the Nile and the Fayum, near the pyramid of King Senwosret II (*c*1880–1874 BC). Over 800 tombs were excavated by Reginald Engelbach and Battiscombe Gunn for the British School of Archaeology in Egypt over the course of one season during the winter of 1913–1914 (Engelbach and Gunn 1923). The cemeteries there range from Predynastic to the Late Period, although the largest concentration of tombs and the richest grave goods date to the Middle Kingdom (*c*2040–1650 BC), which is the best-documented non-royal cemetery of the period (Richards 2005, 88–92). The burials probably relate to the town of Lahun, which was home to the workers who built the pyramid of Senwosret II and served in the king's cult (Richards 2005, 93; Grajetzki 2013, 100).

Tomb 72 in Cemetery A was large, consisting of a vertical shaft leading to two chambers on the north, and one chamber on the south side. All of these had been robbed in antiquity, although they still contained a large quantity of gold leaf, probably lost from wooden coffins, as well as eight ceramic vessels. However, on the west side of the south chamber was another shaft just under a metre deep, which appeared to have gone unnoticed and untouched (Engelbach and Gunn 1923, 14–15, pl 58; Grajetski 2013, 103–5). It contained an intact burial of a young girl, dating to the mid-late 12th Dynasty (*c*1875–1795 BC), wrapped in linen in a wooden coffin that had degraded and adorned with a large quantity of beads and gold jewellery (Table 1). Other finds included a scarab of glazed steatite, decorated with scroll-work and rimmed in gold (84), two uninscribed turquoise scarabs (85–6), two calcite kohl pots (99–100), a haematite kohl stick (98), and a few stone vases and pottery vessels (105–6, 111, now in National Museums Liverpool). The high-value grave goods obtained from distant places – turquoise from the Sinai, shells from the Red Sea, lapis lazuli from Afghanistan, and gold – suggest that the family of the young girl in tomb 72 were wealthy members of the ruling elite.

Table 1: The goldwork and other finds from Haraga tomb 72.

NMS Accession Number	Description	Number used in text	Figure numbers
A.1914.1079	gold catfish pendant	79	1 2 6
A.1914.1080	gold catfish pendant	80	1
A.1914.1081	gold catfish pendant	81	1
A.1914.1082 A	gold tilapia fragment	82A	1
A.1914.1082 B	gold tilapia fragment	82B	1
A.1914.1084	glazed steatite scarab, rimmed in gold	84	1
A.1914.1085	turquoise scarab	85	1
A.1914.1086	turquoise scarab	86	1
A.1914.1087	necklace of semi-precious stone beads	87	
A.1914.1088	necklace of semi-precious stone beads	88	
A.1914.1089	necklace of semi-precious stone beads	89	
A.1914.1090	necklace of semi-precious stone beads	90	
A.1914.1091	string of ribbed gold foil beads	91	1 3 4
A.1914.1092	string of mixed gold beads	92	1 3 4
A.1914.1093	necklace of semi-precious stone beads	93	
A.1914.1094	string of gold ball beads	94	1 4 10
A.1914.1095	necklace of semi-precious stone beads	95	
A.1914.1096	string of mixed bi-conical gold beads	96	1 4 5 10 11
A.1914.1097	string of Red Sea shells tipped with gold	97	1
A.1914.1098	haematite kohl stick	98	
A.1914.1099	calcite kohl pot	99	
A.1914.1100	calcite kohl pot	100	
A.1914.1105	pottery jar (Liverpool 49.56.97)	105	
A.1914.1106	pottery jar (Liverpool 47.56.93)	106	
A.1914.1111	pottery bowl (Liverpool 47.56.109)	111	

The jewellery from this tomb (Fig 1) includes numerous beads of gold and semi-precious stones. The gold beads are heterogeneous and can be separated into five main types, now reassembled in five strings. Most of the beads are reddish in colour and exhibit extensive damage to the gold foil; several of them are now fragmented. However, what makes this assemblage unusual is the presence of five gold catfish and tilapia pendants.

Analytical techniques

Several non-invasive techniques were used to gain information about the morphology of the gold jewellery and their elemental composition, with no surface cleaning or polishing. These techniques allowed high spatial resolution with elemental mapping for the study of the areas around the joints, and were undertaken in air allowing the analysis of the larger and more complex-shaped objects.

The objects were examined visually under an Olympus SZX12 stereomicroscope equipped with an Olympus DP70 digital camera, and by X-radiography using a 320kV Pantak system at NMS. Elemental composition of the alloys was determined using:

- Oxford Instruments ED 2000 air-path X-ray fluorescence spectrometer (XRF), with Rh target X-ray tube collimated to a point of about 2 × 1.5mm, coupled to a Si(Li) detector at NMS;
- μPIXE (particle induced X-ray emission) and PIGE (particle induced γ-ray emission) with a proton beam of 3MeV, an analytical spot of 50μm, Si(Li) and Ge(Li) detectors at the AGLAE accelerator of the C2RMF (Guerra 2004);

Figure 1: The gold jewellery from tomb 72, including beads of different types that were reassembled into five strings (96, 97, 91, 92, 94, from the bottom moving inwards), three scarabs (86, 85, 84, left to right), three catfish pendants and two fragments of the one surviving tilapia pendant (82A, 80, 79, 81, 82B, left to right). Image width 140mm.

- CamScan MX 2500 SEM with a Noran Vantage energy dispersive X-ray analysis (EDS) system, at the optimised analytical working distance of 35.0mm, 300s measurement at electron beam energies of 20 and 25kV at NMS. Images were recorded using the backscattered (SEM-BSC) and absorbed electron (SEM-AEI) detectors.

A range of Au/Ag/Cu standards were used for calibration and the inter-instrument compatibility can be found in Troalen *et al* (2009).

In addition, a fragment of one bead that is heavily corroded was analysed by µXRF with a M4 Tornado from Bruker (30kV, 300µA) comprising a Rh X-ray source with a poly-capillary lens offering a spot size down to 25µm, coupled to a SDD detector. It was also analysed with a Philips XL 30 FEG SEM with a field emission electron source operated with acceleration voltage 10-15kV. The accuracy of quantitative results was validated by the analysis of a set of homemade gold standards (Tissot *et al* 2013).

Finally, a small fragment from the core of a bead from necklace 91 was investigated by X-ray diffraction (XRD). The diffractograms were collected using a Panalytical X'Pert Pro Powder Diffractometer with an Empyrean Cu anode X-ray tube (line focus) running at 40kV, 30mA. Resolution was 0.001° and the scan ran from 5° to 80° 2θ. The XRD patterns were compared to reference materials in the Crystallographic Open Database.

The jewellery from tomb 72

The girl was adorned with hundreds of beads made from semi-precious stones, including carnelian, amethyst, turquoise, and lapis lazuli, in a variety of shapes, including ribbed lentoid beads, drop beads, tiny barrel beads, and graduated ball beads, which may have formed six necklaces (87–90, 93, 95: Aldred 1971, 197, pl 47), or possibly body chains (Grajetzki 2013, 125–6). The gold foil beads were reassembled in four strings (Fig 1) comprising ribbed beads (91), heterogeneous biconical beads (96), ball beads (94), and a mixture of these (92). Another string includes Red Sea shells tipped with gold (97). The excavation report also mentions silver cowrie shell beads, but these do not appear to have been sent to NMS with the rest of the finds (Engelbach and Gunn 1923, 15, pl 22.5).

The most spectacular objects found in the burial were five gold fish pendants (Engelbach and Gunn 1923, pls 10.14, 22.5). The finest catfish pendant (Fig 2) is incredibly lifelike and the details of its speckles, gills, and fins are intricately worked (A.1914.1079: Aldred 1950, 53,

Figure 2: Catfish pendant 79 made of multiple parts, finely decorated by chasing and with the addition of wires to form the hook and the mouth, length 41mm.

pl 74; 1971, 88–98, 213, pl 78; Bourriau 1988, no 159; Oppenheim *et al* 2015, no 137). Fish pendants are only represented being worn by young women and are most often found in female burials. They were particularly popular in the late Middle Kingdom (Grajetzki 2013, 104). While over a hundred of species of fish live in the Nile, most ancient Egyptian fish pendants produced before the Late Period were made in the form of either tilapia fish, from the late Old Kingdom through the New Kingdom, or catfish, which seem to date exclusively to the Middle Kingdom (Brewer and Friedman 1989, 2–4, 67–9; Andrews 1990, 67, 93). An extensive list of examples of fish pendants may be found in Fischer (1977, 161–5). Representations of fish pendants indicate that typically a single pendant was worn from a plait of hair (BM EA 2572: Bourriau 1988, no 140; Andrews 1990, 173, fig 156; Blackman 1953, pl 14) so it is unusual to find five fish pendants in a single burial.

Manufacturing technologies

From visual examination, both the beads and the fish pendants were made from sheets of gold, which were hammered, while the decorative details of the fish pendants were chased, with the parts then being joined together by soldering. The predominant use of soldering instead of mechanical joints in gold jewellery has previously been reported by Vernier (1907–1927) for many objects in the Egyptian Museum in Cairo, by Ogden (2000, 165) in his review of ancient Egyptian metalworking techniques, by Winlock (1934) for the Middle Kingdom jewellery from Lahun, and has also been identified in gold jewellery from the Second Intermediate Period (Troalen *et al* 2009; Troalen *et al* 2014; Miniaci *et al* 2013). The jewellery items from Haraga showed variable levels of wear, indicating different amounts of usage.

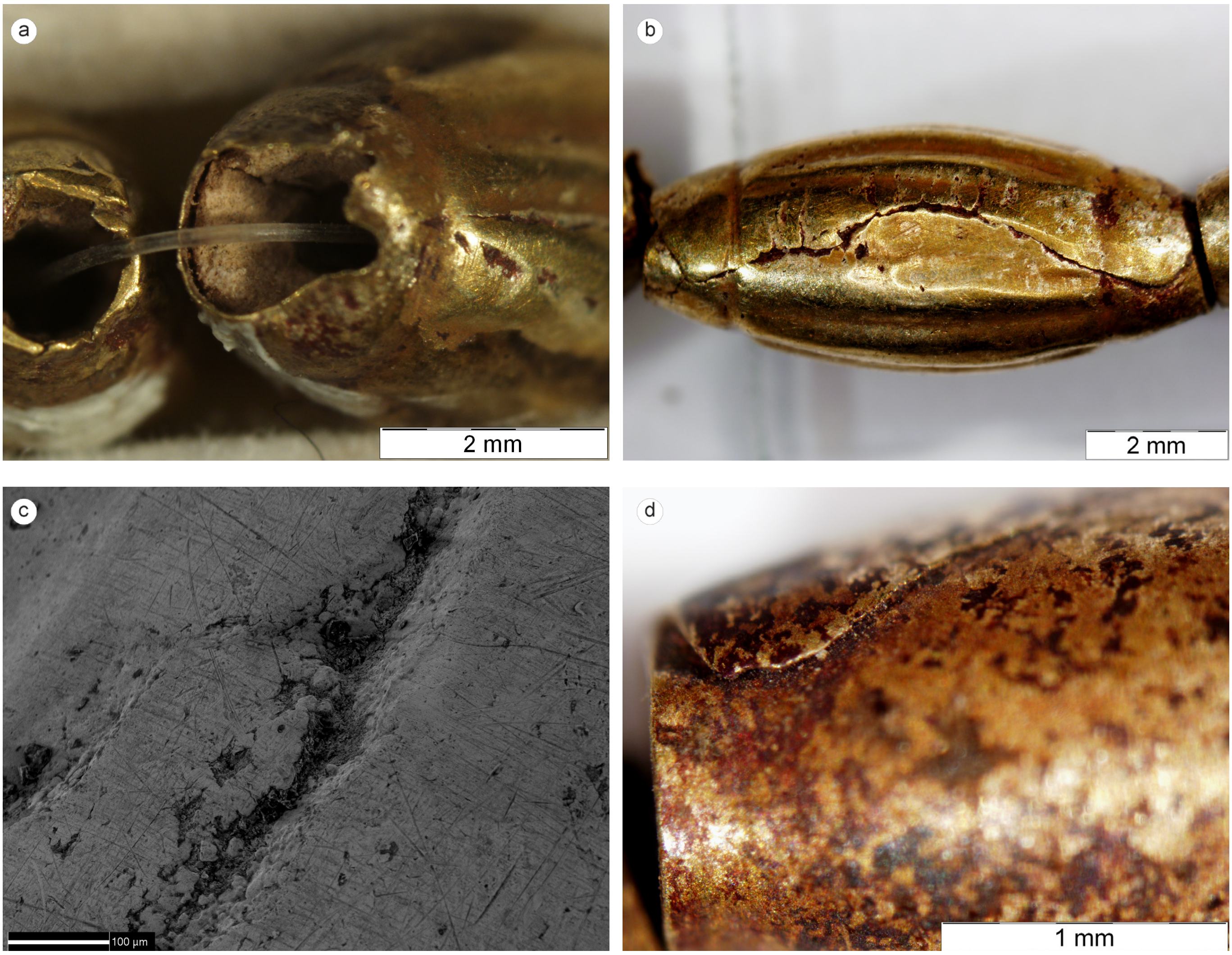

Figure 3: Ribbed biconical gold beads from string 91: a) the lime plaster core; b) the rectangular gold foil rolled around it; c) SEM-AEI image suggesting some heating of the joining area, scale bar 100µm; and d) gold foil join on a biconical gold bead from string 92.

Beads

The different types of beads are all made of gold foils rolled round lime plaster cores, shown to be mainly calcium carbonate and quartz from the XRD data (Fig 3a). The extensive use of this technique in ancient Egypt was described by Petrie (1910) and reported for the finds from Qau and Badari by Beck (1928, 22). The overlapping of the foil in the join on several ribbed and plain biconical beads from strings 91, 92 and 96 seems to indicate that these particular beads were made by rolling a rectangular foil (Figs 3b–3d); there is no visible use of solder in strings 92, 94 and 96 (Fig 3d). In a few cases, the morphology of the gold surface of beads from string 91 suggests heating, and some beads could have been soldered (Fig 3c). It is also possible that both soldering and fusing by heating were used as several strings are made of heterogeneous beads. We were unable to find any difference between the composition of the area of the join and that of the gold-based foil. This could be due to the high use-wear of most of the beads and their high level of degradation, with the morphology of the surface being so altered that the area of the join is now invisible.

The gold foils used to form the beads are of very different thicknesses. Some beads are made with thin gold sheets rolled round lime plaster cores, while others are made from thicker gold foils that are stiff enough without a core. Only the ribbed biconical beads from string 91 are decorated, but these beads exhibit such a high level of use-wear that tool marks are now invisible (Fig 3b).

X-radiographs of the strings revealed different opacities, which can also be seen for beads of the same type (Fig 4). This is particularly so for string 92 and suggests that these biconical beads could have been made with foils not only of different thicknesses but also of different alloys. Almost all the beads – including the gold tips of the Red Sea shell beads – show signs of intensive use-wear, but closer examination of string 92 revealed that a small number of biconical beads show very little use-wear, confirming the varied origins of the beads. Finally, it must be noted that the decay of the gold foils is sometimes so extreme that many beads exhibit a porous surface degenerating into cracking, holes and loss of fragments (Fig 5). Generally, the most altered items are those made from thinner sheets.

Figure 5: Biconical gold beads from string 96. Note the different colours and the now-porous surface and cracking of the foil.

Pendants

The three catfish pendants are more skilfully made than the beads, and of multiple parts soldered together. They do not show the same level of use-wear as the strings of beads. The catfishes' bodies were made by joining two halves to which the tails and the fins were added. The quantity and quality of the decoration on the fishes are variable. The other two pendants were made from thinner foils, which were severely degraded. One no longer survives, while the other is in two thin fragments (82A and B), and the shape of the fragments suggest that it was more similar to tilapia fish.

Pendant 79 is the most delicate, consisting of several added parts, including the fins and a wire to enhance the mouth (Fig 6a). The joins are almost invisible. Details

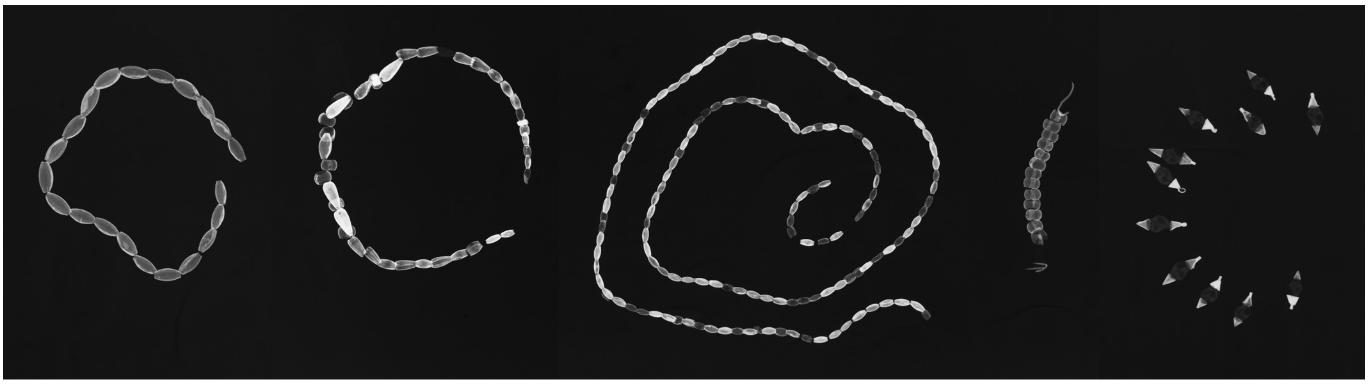

Figure 4: X-radiographs of necklaces 91, 92, 94, 96 and 97 (left to right). The brighter areas correspond to heavy atomic weight (higher gold content) and/or thicker gold foils. Image is c120 mm in height.

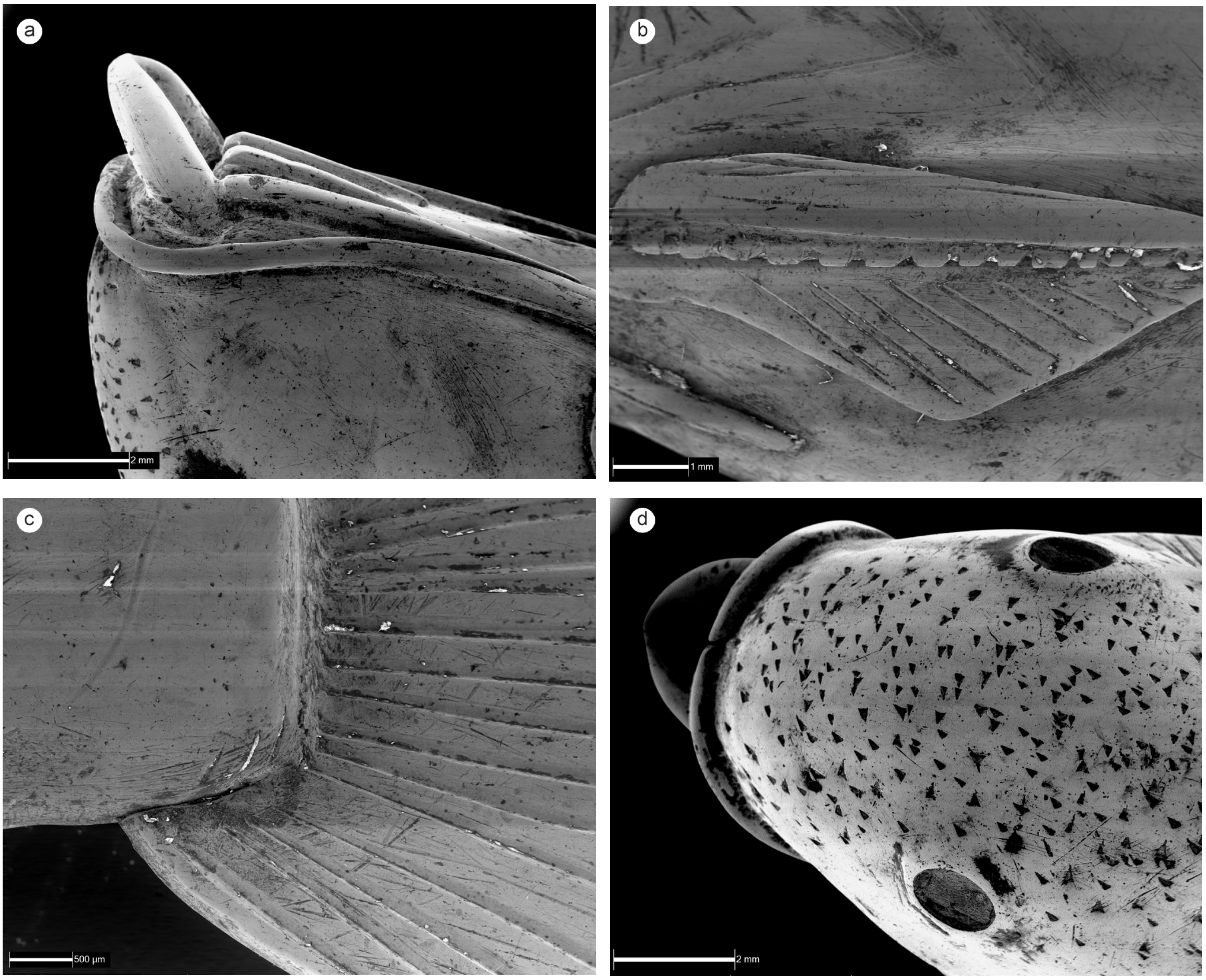

Figure 6: SEM-AEI micrographs of pendant 79: a) the application of wires with visible hard solder, one to enhance the mouth and the other to serve as a suspension ring, scale bar 2mm; delicate chasing of b) the fins, scale bar 1mm, and c) the tail with visible solder, scale bar 500µm; d) punch marks representing the scales on the head and the eyes, now holes, perforated from the reverse, scale bar 2mm.

on all the parts have been further enhanced by chasing (Figs 6b–6c). This is the only pendant of the group where details such as the gills are represented together with the scales on the body (Fig 6d), although pendant 81 is also decorated by punching to imitate the scales. The eyes, where green copper corrosion products can be seen, could have originally been inlaid with semi-precious stones.

It has been suggested that the bodies of each fish could have been made of two gold halves formed on a wood or steatite positive and then filled with finely-levigated clay (Aldred 1971, 88). The late Middle Kingdom fish from Haraga Wadi II tomb 520 in the collection of the Petrie Museum (UC 6411) is in several pieces, revealing that it was made from two thin gold foils over a faience core with a copper-based tail. However all the pendants from tomb 72, even those which are fragmentary, show green corrosion products in the joining areas, especially pendant 80. If the application of copper-base tails for the two fragmentary fishes is excluded, the corrosion products visible through the eyes of pendant 79 could suggest the use of a copper-based core, which is corroborated by the opacity of this pendant when X radiographed at 280kV. It is however also possible that a ceramic core was used for the construction of pendants 79 and 80, but this could not be confirmed by our observations. Aldred (1971, 97) refers to the presence of solders of silver-appearance in fish 81 as Egyptian technology, however it is clear that this pendant has been heavily restored with the different parts re-soldered using a thick modern silver-based solder.

The composition of the alloys

Gold alloys of the strings of beads and the scarab

Figure 7 presents the compositions of the beads constituting the five strings (91, 92, 94, 96 and 97) and the gold foil around the rim of scarab 84. Most of the beads analysed are made of electrum with a silver content of 20–40wt% and a copper content of 2–6wt%. The gold foil around the rim of the scarab has a similar composition. Only the beads from string 94 and some from string 91 exhibit a homogeneous composition suggesting single alloy batches, while the others were found to be made of variable alloys. These variations in composition were suggested by the X-radiographs (Fig 4), with the beads from strings 92 and 96 exhibiting highly variable opacity. The composition of the string of Red Sea shells tipped with gold (97) splits into two groups with different copper contents, which could correspond either to a deliberate polychrome effect, or be the effect of analysing areas of 2 × 1.5mm that represent both the copper-rich solder and the gold foil. It was impossible to check the latter possibility with higher spatial resolution by EDS because a thick lacquer had been applied over the shells.

The silver content of all the gold beads, combined with the observation of a few platinum group element (PGE) inclusions (Ogden 1976) in strings 91 and 92, suggests the use of alluvial gold. The copper content was however higher than the 2wt% expected for alluvial gold deposits in Egypt (Ogden 2000, 162; Klemm and Klemm 2013, 42–43) and suggests an addition of copper to the electrum alloy. The addition of copper to debase gold is known to be common practice from the 18th Dynasty onwards (Lucas and Harris 1962, 229), but this practice seems to have been on-going since the Old and Middle Kingdom periods as high copper contents were also found in aurian silver objects from the Ashmolean Museum, ranging from 0.2–26wt% (Gale and Stos-Gale 1981) and Middle Kingdom gold objects published by Lucas and Harris (1962, 490–491). A high level of copper has been found in the electrum girdle from the Second Intermediate Period Qurna burial, which was made with an alloy containing 3–7wt% copper (Troalen *et al* 2014). In contrast, the gold foils attached to wood cores on objects from Middle Kingdom tombs at Abydos in Upper Egypt were made with gold alloys containing up to 20wt% of silver but with below 1wt% copper, as were the gold foils from Middle Kingdom Haraga tomb 67 from the Petrie Museum that were analysed for comparison (Tissot *et al* 2015).

Gold alloys of the catfish pendants

Figure 8 presents the compositions of the five catfish pendants. Each pendant was found to be made with a different alloy, ranging from high-purity gold to silver-rich electrum. Pendant 79 is made of high-purity gold with a silver content of 7wt% and a copper content below 1wt% with all the parts being remarkably similar in composition. In contrast, the body of pendant 80 is made of an alloy containing 20wt% silver and 1.6wt% copper, while the fins contain 22–23wt% silver and the tail only 13wt% silver (Fig 4). Finally, the body of pendant 81 is made of an alloy containing 17wt% silver and 1wt% copper, while the tail is made of a silver-rich electrum containing 56wt% silver and 3wt% copper. Similar high silver contents were found in the fragments 82A and B,

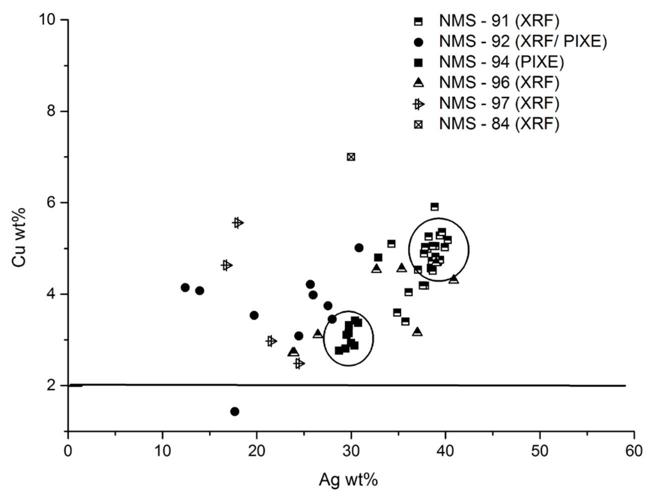

Figure 7: Copper vs. silver content of the strings of beads and scarab from Haraga tomb 72. The two circles indicate single alloy batches. The line at 2wt% copper is the level usually found in Egyptian gold deposits (see text).

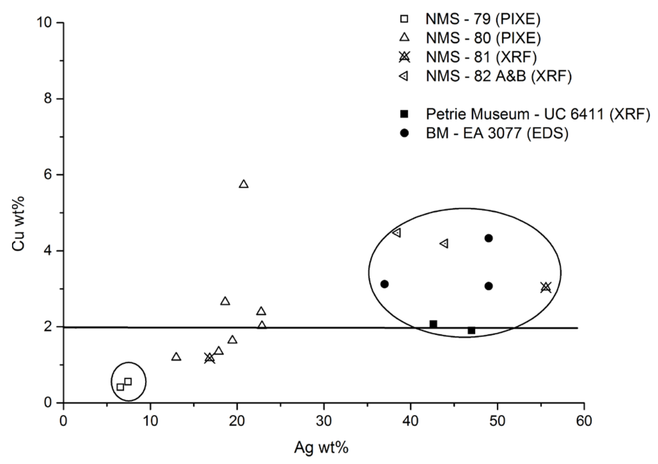

Figure 8: Copper vs. silver content of the catfish pendants from Haraga tomb 72 and other Middle Kingdom catfish pendants from the Petrie Museum and the British Museum. The small circle indicates high-purity gold and the larger one the high silver-content electrum. The line at 2wt% copper is the level usually found in Egyptian gold deposits (see text).

which are also made with an electrum alloy, but one containing 44wt% silver and 4wt% copper.

The composition of the catfish pendants was compared to the now fragmented late Middle Kingdom fish from Haraga Wadi II tomb 520 in the collection of the Petrie Museum (UC 6411; Fig 9c) and two fishes from the Middle Kingdom amuletic string EA 3077 from the British Museum (Figs 9a–9b) which probably originated from different strings (Andrews 1981, 414). The jewellery now consists of beads made of carnelian, amethyst, lapis lazuli, green feldspar and electrum in the form of cowrie shells, catfish, beards or sidelocks of hair, and a gold *heh*-amulet (Andrews 1981, 55). Although the manufacturing technologies are similar, the decoration is different from that of the Haraga pendants, particularly in the case of UC 6411. It was found that the fish pendants from necklace EA 3077 and pendant UC 6411 were also made of high-silver content electrum (Fig 8). These compositions are closer to fragments 82A and B and the tail of fish 81. The colours of EA 3077 and UC 6411 are whitish-greenish yellow, while fish 80 and the body of 81 are yellow-green yellow, and 79 is yellow (based on McDonald and Sistare 1978; Rapson 1996).

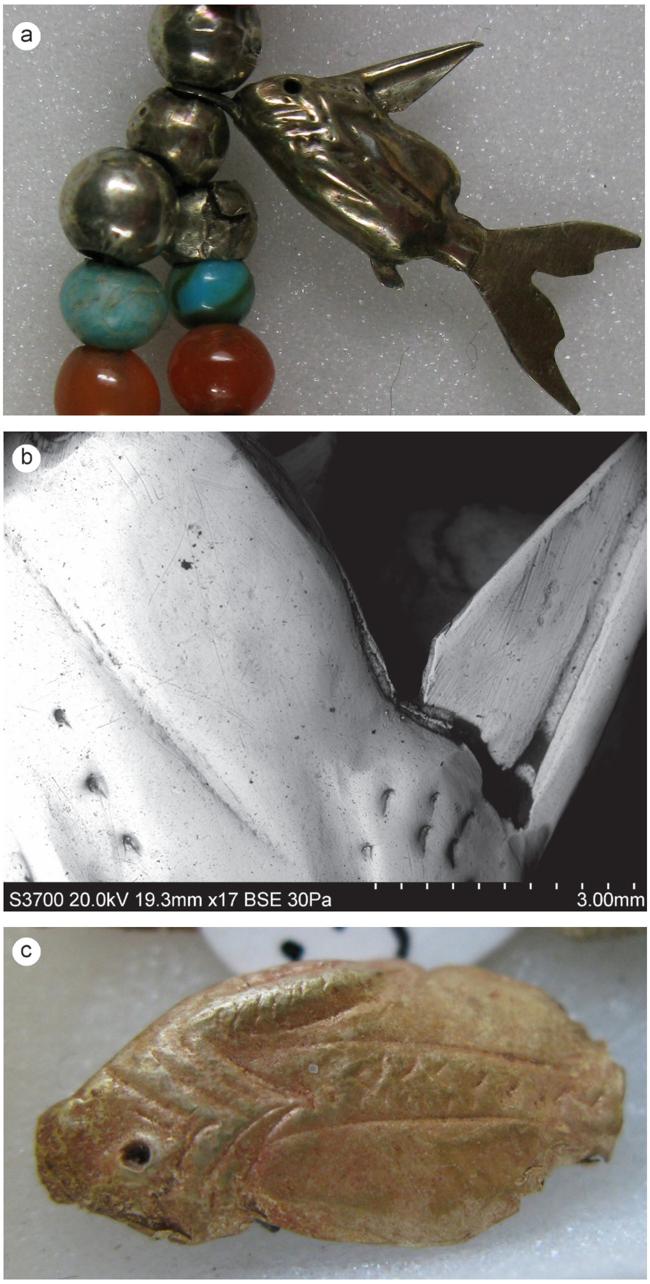

Figure 9: a) One of the two fish from the Middle Kingdom amuletic string EA 3077 from the British Museum, length c15mm; b) SEM-BSE micrograph of the soldered parts forming the pendant, scale bar 3 mm; and c) the most complete fragment of the late Middle Kingdom fish UC 6411 from Haraga Wadi II tomb 520 (Petrie Museum collection), length 28mm.

PGE inclusions were observed in pendants 80 and 81, as well as in one of the fish pendants from necklace EA 3077. The composition of the alloys and the presence of PGE inclusions seem to indicate the use of alluvial gold (Ogden 1976), similar to the beads, with some addition of copper to the silver-rich electrum alloys. The analysis of one inclusion present in the tail of pendant 81 showed an iridium-osmium-ruthenium alloy with a composition of 38wt% iridium, 45wt% osmium and 17wt% ruthenium, corresponding well to the type of compositions expected for Egyptian deposits (Meeks and Tite 1980; Troalen *et al* 2009; Troalen *et al* 2014; Miniaci *et a*l 2013; Troalen and Guerra 2016).

Corrosion study

The majority of the beads in the four strings have a corroded surface, which shows some cracking, holes and fragmentation, as well as a heterogeneous dull red coloration. Figures 10a–10b illustrate the cracks and the mechanical deformation of the foils of the ball beads of string 94 and of the biconical beads of necklace 96. In contrast, the fish pendants, except the two fragmented pendants made of thinner gold foils, are in a good state of preservation.

One bead from string 96 was selected for the identification of the corrosion products. The porous surface texture of the fragment of this bead, revealed under the FEG-SEM, indicates that annealing during the production process of the gold foil by hammering was incomplete (Fig 11). The same type of porous structure seems to be visible under the SEM at lower magnification (Figs 10a–10b). The annealing temperatures used in the manufacture of most of the beads from Haraga tomb 72 were below those required to obtain a homogenous alloy surface (for modern gold alloys with similar composition the annealing temperature is between 704 and 760°C), as shown in Figure 11a, leading to a less hard

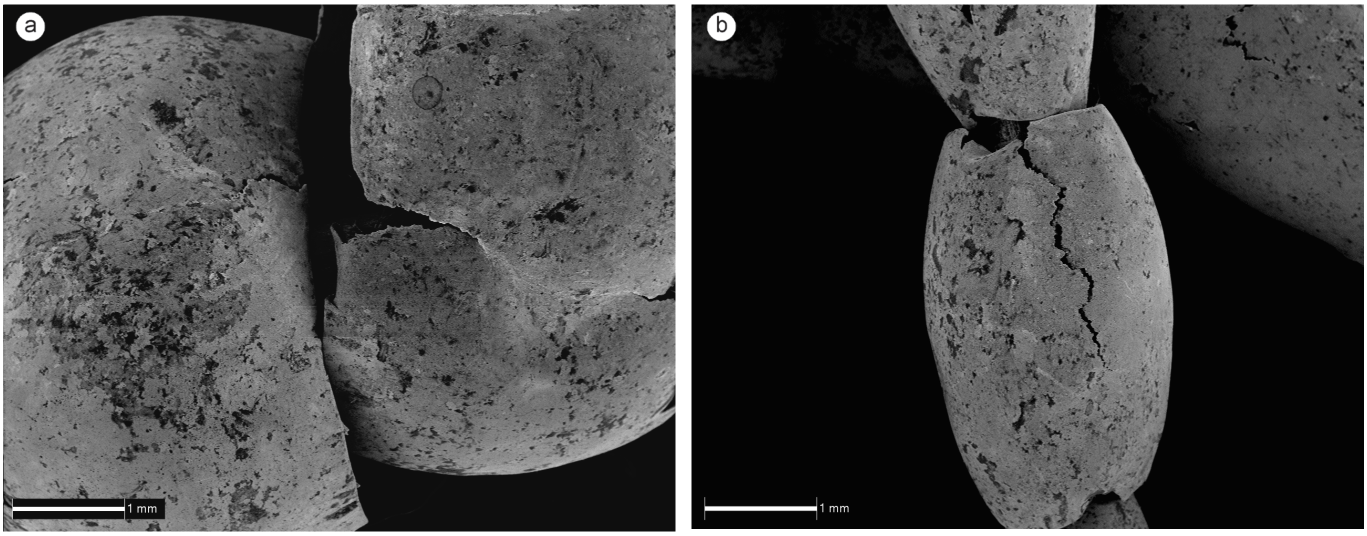

Figure 10: SEM-AEI micrographs of beads exhibiting a high level of corrosion with cracking of the gold foils: a) from string 94, and b) string 96, scale bars 1mm.

surface with material cracks and fractures (Riabkina *et al* 1984). It is known that porosity increases the surface exposed to atmospheric corrosion, which can accelerate the rate of stress corrosion cracking and tends to increase the overall risk of damage to the gold foil (Rapson 1990).

Until their archaeological discovery, the strings of beads remained in a grave context containing silicates. The corrosion products on the surface of the beads are mixed with those silicates, which prevented the formation of a homogeneous corrosion film. Notwithstanding, the corrosion film is formed of different layers (Fig 11b), consisting of agglomerates of round nanoparticles of sulphur compounds, similar to the corrosion layers observed in Egyptian gold foils from Abydos (Tissot et al 2015). Elemental analysis by µXRF showed that the concentration of sulphur increases with the decrease of the copper and gold contents in the corroded areas indicating the formation of silver-sulphur corrosion products, characteristic of the corrosion of gold-based alloys (Guerra and Tissot 2013; Rifai and El Hadidi 2010). The quantified gold, silver, copper, and sulphur contents for selected areas across a line-scan area are given in Table 2. The data obtained for the Haraga bead is in good agreement with the data published for a few

Table 2: Composition (wt%) determined by µXRF spot analysis of a bead fragment removed from string 96.

	S K_α	Cu K_α	Ag L_α	Au L_α
Substrate	0.1	3.1	34.2	62.6
	0.1	3.0	34.8	62.1
	1.0	2.6	34.5	61.9
Corrosion area	2.1	2.8	34.4	60.8
	2.3	2.7	33.7	61.3
	2.3	2.8	34.1	60.8

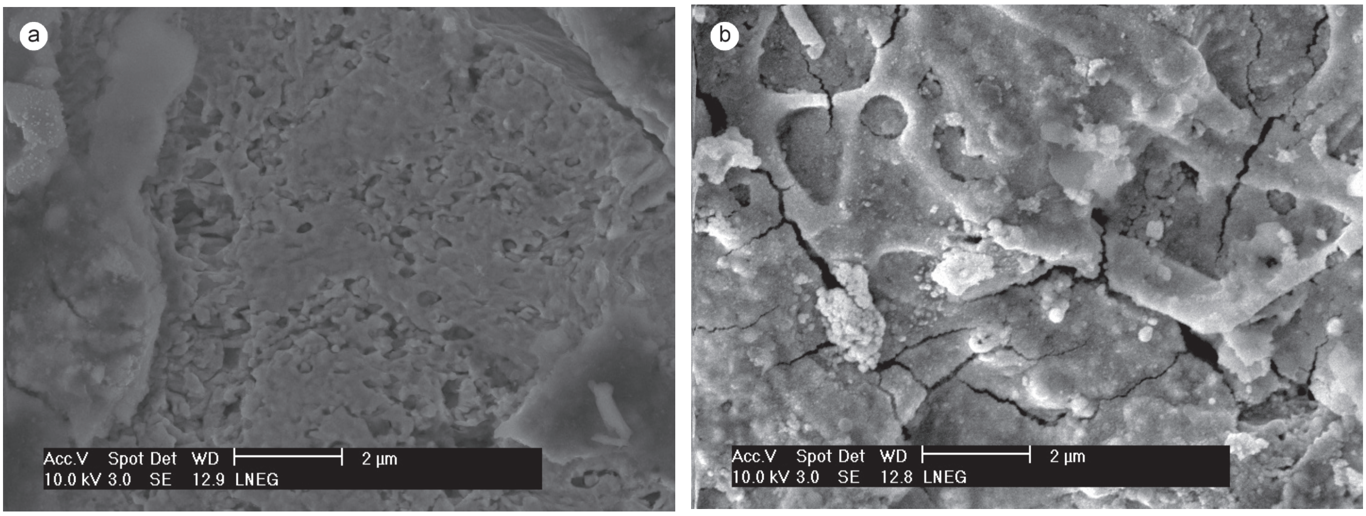

Figure 11: FEG-SEM-SE micrographs of the fragment of one bead from necklace 96. a) gold foil with heterogeneous surface due to failed annealing; and b) corroded surface composed of different heterogeneous layers of corrosion products mixed with silicates from the burial.

corroded gold Egyptian objects studied by Frantz and Schorsch (1990), who identified the presence of silver sulphide complexes as surface corrosion products.

Conclusions

The investigation of the Middle Kingdom gold jewellery from Haraga tomb 72, belonging to an intact burial of a young girl, revealed the use of gold alloys ranging from high-purity gold to silver-rich electrum, the presence of several levels of use-wear, and the use of low annealing temperatures that accelerated the degradation of several items.

Analysis of the pendants and gold beads by XRF and PIXE/PIGE has shown that the majority were made from silver-rich electrum with 20–40wt% silver and with systematic additions of up to 7wt% copper, possibly to change the properties of the alloys. The Middle Kingdom fish pendants from the British Museum and the Petrie Museum, also analysed in this work, are also made from silver-rich electrum. Only the most skilfully-crafted fish pendant from tomb 72 was made with a high-purity gold alloy containing less than 7wt% silver and almost no copper. These gold alloy compositions cover a similar spectrum of colour (based on McDonald and Sistare 1978; Rapson 1996) to those seen in the Second Intermediate Period Qurna burial (Troalen *et al* 2014): from yellow to whitish. In the case of Haraga, the silver-rich electrum alloys predominate over the gold alloys, while in Qurna it is only the beads from the adult's girdle that are made of silver-rich electrum, containing on average 53wt% silver.

The quality of the best catfish pendant (79; Fig 2) is reminiscent of the highly skilled jewellery from the burials of the 12th Dynasty royal women at Lahun described by Winlock (1934). In comparison, the other catfish and tilapia pendants were found to be of lesser craftsmanship and made with alloys containing higher levels of silver and copper. These differences in both alloys composition and craftsmanship might perhaps suggest that fish pendant 79 could have been a royal gift. The other pendants may then have been commissioned to complement it. Although fish pendants seem to have generally been worn singly from a plait of hair, since the burial of the young girl in tomb 72 contained three larger fish and two much smaller ones, they may have been strung in a symmetrical arrangement on a necklace. A comparable example of this is a necklace depicted in the tomb of Ukhhotep IV at Meir, in which the usually solitary oyster shell gold pendant has been strung in a group of five pendants graded in size (Blackman 1953, pl 11 bottom row, right).

The gold beads were found to be of five types and were made by rolling foils of different thicknesses on a lime plaster core. Several beads are highly corroded and fragmented, with a heterogeneous dull red coloration, characteristic of the atmospheric corrosion of gold-based alloys, which indicates the formation of gold-silver-sulphur compounds on the surface of the objects. The jewellery from Lahun also presented high levels of corrosion, as reported by Kopp (in Winlock 1934, 73–75). The microscopic observation in the FEG-SEM of one corroded fragment revealed the porous texture of its surface that corresponds to poor control of the annealing temperature, below that required. The porosity of the surface can increase the rate of stress corrosion cracking which explains the poor preservation of the beads. Agglomerates of round nanoparticles of sulphur compounds were observed on the surface of the foil. The surface corrosion is composed of different layers of gold-silver-sulphur compounds morphologically similar to those found on other corroded Egyptian gold foils (Tissot *et al* 2015).

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