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Analytical study of the Middle Kingdom group of gold jewellery from tomb 124 at Riqqa, Egypt

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The jewellery from tomb 124 at Riqqa, consisting of one pectoral and one winged beetle in gold and cloisonné work, one gold shell pendant decorated with wires and granulation, and one hollow gold amulet in the form of god Min, was analysed by handheld X-ray fluorescence and scanning electron microscopy with energy-dispersive X-ray spectroscopy. This group of jewellery, dated to the second half of the 12th Dynasty (c. 1900–1840 B.C.), was excavated inside the coffin of an adult male, which had been crushed after burial by the collapse of the chamber roof during an episode of looting. Both the male and the looter's body were found inside the chamber, evidencing that the group of jewellery was intact. Despite having been highly restored in the past, as referenced in the correspondence between the excavator Flinders Petrie and the curators of the Manchester Museum, it could be shown that the jewellery was produced using Ag-rich electrum alloys containing platinum group element inclusions that indicate the use of alluvial gold. The analysis of some joins has confirmed the use of hard-soldering, with solders obtained by addition of Cu to the base-alloy. Data obtained for the jewellery of tomb 124 were compared with data previously obtained for tomb 296, also excavated at Riqqa, but dated to the 18th Dynasty. The comparison demonstrates the continuity of the workshop traditions in one location between the Middle Kingdom and the New Kingdom but also reveals discrepancies in the alloys employed in those two periods.

1 | INTRODUCTION

Excavated on behalf of the British School of Archaeology in Egypt at the end of 1912 by Flinders Petrie's assistant Reginald Engelbach, the cemeteries discovered at Riqqa, located close to the mouth of the Faiyum region, contain a series of graves ranging from the Predynastic to the Late Period.[1] It is at Riqqa that two of the most significant groups of Egyptian gold jewellery currently known were found.[2] One of the groups, dated by Flinders Petrie to the 18th Dynasty (c. 1550–1290 B.C.), was found in tomb 296 in cemetery C, inside two coffins, which contained the burial of scribe Beri.[3] The recent analytical study of four penannular gold earrings and a string of several types of gold beads and amulets from tomb 296[4] has shown the use, within the same burial, of a variety of gold and electrum alluvial alloys containing platinum group element (PGE) inclusions. A well-defined jewellery mounting practice could also be revealed: several small parts were methodically hard-soldered to form the objects; the solder alloys were obtained by the addition of copper to the base alloys. It could also be demonstrated that two penannular gold earrings of the same type, which are a traditional 18th Dynasty production, found elsewhere at Riqqa, one in the collection of the Petrie Museum of Egyptian Archaeology and another in the collection of the Manchester Museum (MM), form technologically one pair.[4]

The second large group of jewellery from Riqqa was found in cemetery A, tomb 124 dated to the second half of the 12th Dynasty (c. 1900–1840 B.C.), inside a coffin containing the remains of an adult male. This group includes a gold pectoral and a gold winged beetle, both in cloisonné work forming the name of King Senwosret II (c. 1897–1878 B.C.), a gold shell pendant bearing the cartouche of King Senwosret III (c. 1878–1839 B.C.), and a hollow gold pendant in the form of the fertility god Min (Figure 1).[5] The jewellery suffered from the chamber roof fall due to the looters' break-in. On the top of the crushed coffin were found the arm-bones of another body. The position of both the bones and the coffin led Engelbach to suggest that one looter “had been suddenly crushed while in a standing, or at least a crouching position, when the fall occurred,” probably when unwrapping the mummified body to steal the jewellery.[1]

If Engelbach's assumption is correct, it can be assumed that the objects found in the burial are the complete group of jewellery from tomb 124. Because the jewellery had been damaged by the roof fall, it was consequently restored, and some parts may now be modern. A short letter written by Flinders Petrie on 8 November 1913 to Winifred Crompton, Assistant Keeper of Archaeology at MM, indicates that the pectoral was flattened by a goldsmith at Petrie's behest, but the attempts made to restore the damaged god Min amulet were unsuccessful: “it was originally quite straight, but bent by the fall of the roof. Nothing could straighten it unless the silver was dissolved out electrically, and then the gold could be such a sponge that it would look much duller than now. No jeweller could do anything for it. A good chemist might perhaps improve it. The best repairer at Oxford, who flattened the pectoral, could do nothing for the Min”(MM archive ID 332).

Now in the collection of the MM, the amulet is close to its original form, but the methodology followed by the restorer is unknown. Nevertheless, the Middle Kingdom group of jewellery from tomb 124 (Figure 1) provides a unique opportunity to draw for one single location, Riqqa, a chronological parallel of the workshop practices in Egypt between the Middle Kingdom and the New Kingdom. The jewellery from tomb 124 is studied in this work using stereomicroscopy, handheld X-ray fluorescence (p-XRF), and scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS) and is compared with the recently published New Kingdom group of jewellery found in tomb 296.[4]

2 | EXPERIMENTAL DETAILS

2.1 | Analysed objects

Engelbach provides a short description of the group of jewellery from tomb 124 at Riqqa, today in the collection of the MM, and the location of the finds in the burial.[1] An incomplete winged beetle supported by lotus flowers in gold and cloisonné inlaid with lapis lazuli, carnelian, and turquoise (MM 5967) was found on the chest of the mummified man. Although the piece is incomplete, as the beetle's head and the major part of the upper legs, and the sun disk are missing, the pendant is almost identical to a piece from the British Museum collection (EA54460[6]), which like MM 5967 has no *cloison* to separate the

FIGURE 1 (a) The gold pectoral, (b) figurine of god Min, (c) the gold shell, and (d) the gold winged beetle from tomb 124 at Riqqa (Manchester Museum, Acc. No.: MM 5966, MM 5969, MM 5968, and MM 5967), photo M. F. Guerra

coloured materials inlaid on the beetle's wings. Its observation under the stereomicroscope confirmed that the objects were quite restored, but the restored parts are easily identified. Remains of a modern lead-tin solder are visible in many joins. A few small parts are modern additions, replacements for those that were broken and lost. Among them, the beetle's lower legs are made from modern plain round-section wire, unlike the original upper legs, which are flat and were made by cutting a gold sheet. Remains of the ancient upper legs are still visible on the object, but like the other ancient parts, they are quite tarnished. The lotus flowers, which are ancient like the beetle's wings (Figure 2), were enhanced on the reverse by chasing and engraving, possibly at different times as the engraved lines seem quite *fresh* and could therefore be modern.

The beetle could have formed a group with the gold pectoral (MM 5966), found slightly displaced on the mummified man's chest, as together they form the name of King Senwosret II. The pectoral, in gold cloisonné inlaid with lapis lazuli, carnelian, and turquoise, represents two birds on either side of an *ukh*-pillar, each standing on the hieroglyph for *gold*, flanked by papyrus plants, and above, two *wedjat*-eyes flanking a sun disc. No *cloison* separates the majority of the materials inlaid, but the small round *cloisons* adjacent to the birds' feet, made in hammered strips of gold, demonstrate the skilled work of the Egyptian goldsmith (Figure 3a). The same motif was chased on the reverse; the several engraved lines that can also be seen probably result from the restoration process. Figure 3b shows a region containing cracks and scratches from the restoration process that included cleaning, heating, and hammering, but only the *ukh*-pillar base is a modern addition.

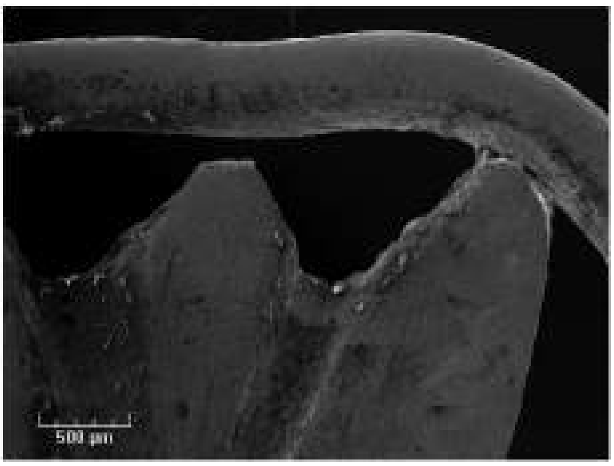

FIGURE 2 Scanning electron microscopy secondary image (SEM-SEI) showing a detail of the reverse of the ancient lotus flower in the winged beetle pendant (MM 5967), scale bar is 500 µm

Two gold suspension rings are soldered to the base plates of both the beetle and the pectoral, indicating that they were worn hanging, likely on a string of beads, perhaps made with those found free in the tomb. Other Middle Kingdom pectorals bearing a royal name are suspended in a string of beads; examples are those from the royal tombs at Dahshur and Lahun.[2,5,7–10] However, although the beetle's suspension rings are made by rolling gold strips, those on the back of the pectoral are coiled strip-drawn wires. This fact reveals the work of two artisans.

On the man's chest, close to the beetle, was found a gold pendant in the form of a shell made by hammering, decorated with a motif in filigree and granulation representing a *uraeus* on each side of the cartouche of King Senwosret III (MM 5968). The shell is one of the earliest examples in Egypt of the skilled decoration technique of granulation. Although granulation was already used to decorate third millennium B.C. jewellery from Ur,[11,12] it was not until the New Kingdom that this technique was extensively and skilfully used in Egypt.[13] So far, the earliest examples in Egypt of jewellery with motifs made using wires and granulation were found in 12th Dynasty tombs. The most representative examples belong to the jewellery groups from Dahshur, one found in Princess Khnumet's burial, whose objects are reminiscent of Eastern Mediterranean and Asiatic goldworking,[10,12,14,15] and another found in Princess Mereret's burial.[16]

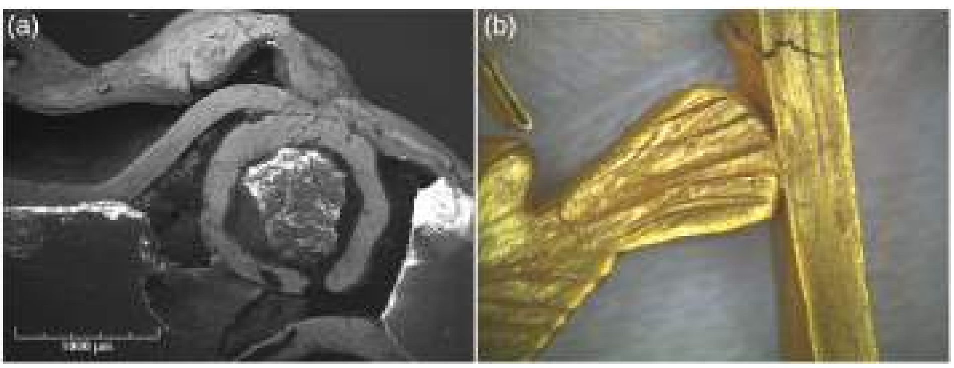

FIGURE 3 Details of pectoral (MM 5966): (a) scanning electron microscopy secondary image (SEM-SEI) showing the skilled cloisonné work, scale bar is 1000 µm and (b) stereomicroscopic image showing the surface scratches and cracks caused by restoration

There are no signs of restoration on the shell, except surface scratches from a strong mechanical cleaning. The shine on the shell's surface could be the result of a chemical cleaning. The wires, made by rolling a strip of gold (Figure 4), a kind of strip-drawing,[13,17,18] were cut and soldered to the shell. The suspension ring is a rolled gold strip soldered to the top of the shell.

Finally, behind the mummified man's neck, was found a small hollow gold pendant in the form of fertility god Min (MM 5969), standing on a stepped platform. Like for the pectoral and the winged beetle pendant, the (broken and incomplete) god's cloisonné feathered crown is inlaid with lapis lazuli and turquoise not separated by *cloisons*. On the reverse, the main feather veins are hollow wires soldered to the gold sheet where the barbs were cut and chased. The incomplete figure is very tarnished, with signs of severe restoration to reform the body that, as hollow, was certainly crushed when the chamber roof collapsed. On its back, a suspension ring made from a rolled strip of gold—one of the original two is missing—indicates that the object was originally suspended. No tool marks could be identified on the tarnished and highly cleaned surface.

2.2 | Analytical methods

All the objects were visually examined under a stereomicroscope equipped with Dino-Eye digital ocular camera Am7023X. The elemental composition of the alloys and of some inlaid materials was determined by scanning electron microscopy with energy-dispersive X-ray spectroscopy and handheld X-ray fluorescence (p-XRF) using the following equipment:

- SEM-EDS was carried out with a JSM-5300 microscope with an ultrathin window detector controlled by a PGT Spirit system. Analysis was undertaken at 20 kV acceleration voltage with 100 s acquisition time. Elemental quantification was done using pure element and mineral standards for calibration with the ZAF matrix correction model.
- p-XRF was carried out with a handheld Thermo Scientific Niton XL3t analyser set to *Precious Metals* alloy mode, with a *GOLDD* detector, a 50 kV, 200 μA X-ray tube with Ag anode, a 3 mm spot collimator, and a charge-coupled device (CCD) camera for locating the regions of analysis. The compositions given in this work were measured using an acquisition time of 60 s and correspond to the average data obtained for three analyses.

These noninvasive techniques provide the composition of the gold objects' surface.[4,19] The effective penetration depth, corresponding to the thickness in μm from which 95% of the detected X-rays are produced, for ternary gold alloys containing high Ag contents, such as those that are studied in this work, is 10–60 μm for XRF and 0.5–0.6 μm for EDS, depending on the element considered and the energy of the X-ray lines used for elemental quantification.[19] The very thin layer that is analysed by EDS, and the possibility of building elemental scans, makes this technique one of the most appropriate when studying small details such as joins, wires and granulation. On the contrary, for the tarnished and thermo-mechanically restored parts of the studied jewellery, only the data obtained by p-XRF are considered in the following sections.

A set of gold-copper-silver alloys was used to check the confidence level of the analytical results obtained by p-XRF: GCS7 produced in collaboration with the British Museum and the Research Laboratory for Archaeology and the History of Art (RLAHA); a gold roll standard purchased from Johnson Matthey; standards A1, A2, and E1 produced by professional goldsmiths in the scope of European project Authentico ID44480, and all certified by several techniques.[13,20] Figure 5 provides a comparison of the values obtained by particle-induced X-ray emission analysis (PIXE) using a 3-MeV proton beam and p-XRF measured concentrations of Au, Ag, and Cu showing the good accuracy of the technique for the objects to be

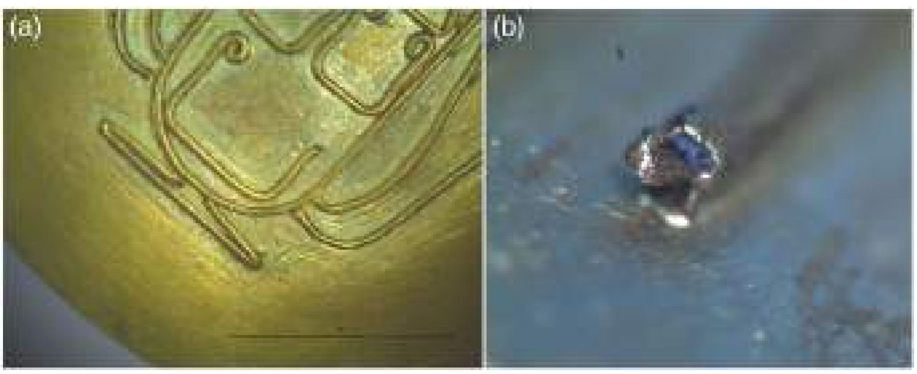

FIGURE 4 Stereomicroscopic images of the shell pendant (MM 5968) showing (a) the scratched surface and the decorative pattern and (b) a detail of the hollow wire

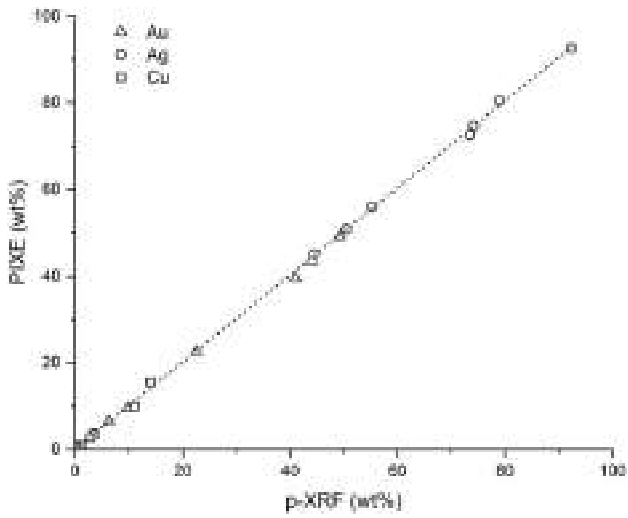

FIGURE 5 Data obtained by p-XRF for the set of gold-copper-silver alloy standards compared with values obtained by PIXE

TABLE 1 Certified values (CV) compared with those determined by three consecutive p-XRF measurements and those previously obtained by repeated PIXE analysis, all normalised to 100 wt%

Gold-copper-silver Standards		wt%		
		Au (L_α)	Ag (K_α)	Cu (K_α)
Gold roll	CV	80	10	10
	PIXE	80	10.7	9.3
	p-XRF	79.9	10.0	9.8
	σ	0.1	0.0	0.1
GCS7	CV	45	39.8	15.2
	PIXE	44.5	40	15.5
	p-XRF	44.7	40.7	14.2
	σ	0.3	0.5	0.1
A1	CV	92	6	1
	PIXE	92.6	6.4	1.0
	p-XRF	92.3	6.3	1.1
	σ	0.2	0.0	0.0
A2	CV	70	27	3
	PIXE	74.6	22.6	2.8
	p-XRF	74.2	22.7	2.9
	σ	0.0	0.1	0.0
E1	CV	50	50	
	PIXE	50.8	49.2	0.0
	p-XRF	50.5	49.3	0.0
	σ	0.1	0.0	0.0

analysed. The five standards of very different compositions were analysed three consecutive times to reproduce the experimental conditions. Table 1 provides the average and standard deviation of the concentrations obtained, showing that the precision is always <0.2 wt%, except for one alloy containing high contents of both Ag and Cu.

3 | RESULTS AND DISCUSSION

The aim of this work being the analytical study of the gold parts of the jewellery from tomb 124, only a few inlays of different colours set in the gold *cloisons* of the pectoral (MM 5966), were analysed qualitatively by SEM-EDS. The elements visible in the EDS spectra are reported in Table 2 confirming that the stones used for the inlays were the most popular,[21] which means light blue-green turquoise, red carnelian, and dark blue lapis lazuli.

The data obtained by p-XRF for the ancient metallic parts identified in the jewellery are summarised in Table 3, showing that all the alloys are Ag-rich electrum with Ag contents ranging from 27 to 49 wt%. The results obtained for each object are quite homogeneous as shown in the diagram of Figure 6 where the Cu and Ag contents in wt% are plotted.

The god Min amulet (MM 5969) contains the highest Ag contents, which vary from 44 to 49 wt%, a discrepancy certainly caused by the severely tarnished and restored surface. The object shows areas of different colours that go from reddish to blackish, suggesting different phases of corrosion.[22,23] Zn was also detected in several parts of the amulet by p-XRF. The EDS analysis shows levels of Zn up to 28 wt%. These results indicate the high level of restoration of the crushed parts of the amulet, consistent with early 20th century restoration work.[24] Similarly, the restored parts of the winged beetle pendant also show the presence of Zn by p-XRF (Table 3).

The base alloys employed in the manufacture of the winged beetle pendant (MM 5967) and the pectoral (MM 5966) both exhibit high levels of Ag but are made of different alloys. The winged beetle pendant contains 42–43 wt% Ag and about 2.5 wt% Cu. The pectoral shows lower and quite homogeneous Ag and Cu contents, respectively 28–29 wt% and about 1.5 wt%. For

TABLE 2 Data obtained by EDS for the a few inlays from the pectoral (MM 5966)

Pectoral (MM 5966)	Elements detected	Suggested identification
Light green inlay	O, Al, P, Ca, Cu	Turquoise
Light blue inlay	O, Al, P, Cu	Turquoise
Red inlay	O, Si	Carnelian
Dark blue inlay	O, Na, K, Mg, Al, Si, S, K, Ca, Cu	Lapis lazuli

TABLE 3 Elemental composition obtained by p-XRF and EDS for the different parts that constitute the jewellery items from tomb 124 and normalised to 100 wt%. * for EDS analysis Au (M_{α}) and Ag (L_{α}) lines were used for quantification.

			In wt%			
Area of analysis	Technique		Au* (L_{α})	Ag* (L_{α})	Cu (K_{α})	Zn (K_{α})
Shell (MM 5968)						
Front	p-XRF	Average	68.4	29.2	2.4	
		σ	0.4	0.4	0.1	
Back	p-XRF	Average	67.8	29.4	2.8	
		σ	0.5	0.4	0.1	
Ring	p-XRF		71.9	26.6	1.5	
Granule	EDS		88	11	1	
Wire	EDS		91	7	2	
Winged beetle (MM 5967)						
Lotus flower back	p-XRF	Average	54.7	42.8	2.5	
		σ	0.4	0.2	0.2	
Wings back 1	p-XRF	Average	54.2	43.2	2.6	
		σ	0.0	0.1	0.2	
Wings back 2	p-XRF	Average	56.3	41.5	2.2	
		σ	0.2	0.4	0.2	
Average modern/ancient wires	p-XRF	Average	45.4	46.1	8.4	2.2
		σ	1.1	1.6	0.5	0.1
Lotus flower back	EDS		68	30	2	
			65	34	1	
Suspension rings	EDS		86	13	1	
			81	18	1	
Pectoral (MM 5966)						
Wedjat-eyes back	p-XRF	Average	70.5	27.9	1.6	
		σ	0.5	0.3	0.2	
Wedjat-eyes side	p-XRF	Average	70.7	27.6	1.7	
		σ	0.6	0.7	0.1	
Birds back	p-XRF	Average	69.0	29.3	1.6	
		σ	0.3	0.3	0.0	
Under pillar back	p-XRF	Average	68.8	29.9	1.3	
		σ	0.4	0.4	0.0	
Papyrus back	p-XRF	Average	70.3	28.2	1.5	
		σ	0.6	0.7	0.1	
Papyrus side	p-XRF	Average	68.8	29.4	1.8	
		σ	0.2	0.1	0.2	
Rings	p-XRF	Average	63.8	33.5	2.7	
		σ	0.3	0.2	0.1	
Min amulet (MM 5969)						
Platform	p-XRF	Average	49.0	48.8	2.2	
		σ	0.2	0.5	0.2	

(Continues)

TABLE 3 (Continued)

			In wt%			
Area of analysis	**Technique**		**Au* (L_α)**	**Ag* (L_α)**	**Cu (K_α)**	**Zn (K_α)**
Body	p-XRF	Average	53.3	45.5	1.2	
		σ	1.4	1.8	0.4	
Head	p-XRF	Average	51.0	46.5	2.5	
		σ	0.2	1.3	1.1	
Legs	p-XRF	Average	52.1	46.1	1.8	
		σ	1.4	0.4	1.0	
Flag	p-XRF	Average	52.5	45.2	2.3	
		σ	0.3	0.7	0.4	
Arm	p-XRF	Average	53.3	44.4	2.2	1 to 5
		σ	0.1	0.4	0.2	
Crown	p-XRF	Average	50.5	47.2	2.4	
		σ	0.5	0.9	0.4	
Body	EDS		57	11	5	28
Face	EDS		55	38	3	4
Neck	EDS		66	13	5	16

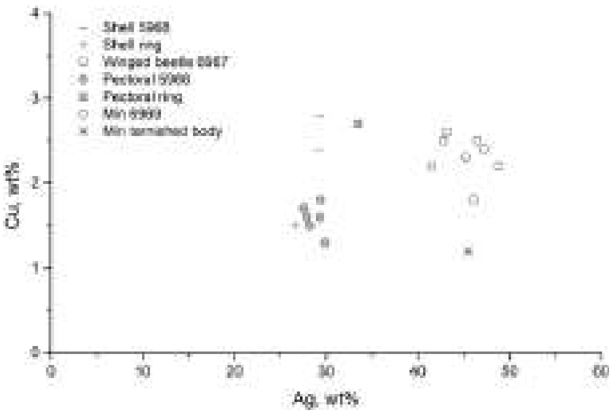

FIGURE 6 Ag and Cu contents (in wt%) obtained by p-XRF for the jewellery from tomb 124

FIGURE 7 Scanning electron microscopy secondary image (SEM-SEI) of joining area identified in pectoral MM 5966, scale bar is 1000 μm

both items, the suspension rings are made from different alloys (Table 3). Those from the pectoral exhibit higher levels of Cu, possibly due to the presence of solder to join the loops of the wire. The surface tarnishing and the different depths of analysis of the employed techniques can explain the different amounts of Ag obtained for the base sheets by p-XRF and EDS (Table 3). The original joins of the pectoral (Figure 7) were analysed by EDS revealing the use of a solder containing higher level of Cu than the gold base alloy (Table 4). Such soldering technology seems to have been traditionally used in Egyptian workshops.[4,19]

The shell pendant (MM 5968), also much cleaned but less tarnished, is made with an alloy containing around 29 wt% Ag and 2.5 wt% Cu, but its suspension ring is made from a slightly different alloy that contains about 27 wt% Ag and 1.5 wt% Cu. The granules and wires are as expected[20,25] made from higher quality alloys.

Despite the use of portable equipment for the majority of the noninvasive analysis carried out in this work, the compositions obtained by p-XRF for the jewellery from tomb 124 match the published data of other important jewellery from Middle Kingdom.[26–28] However, due to the extent of the conservation work, it is difficult to make further comments on the data obtained.

TABLE 4 Elemental composition obtained by EDS of the cell plate and the solder alloy in one of the original join identified in pectoral (MM 5966), normalised to 100 wt%

	In wt%		
Area of analysis	**Au (M_α)**	**Ag (L_α)**	**Cu (K_α)**
Solder	70.5	26.4	3.1
Cell plate	73.2	25.2	1.6

3.1 | Gold sources and PGE inclusions

The few published works focusing on the analysis of Ancient Egyptian jewellery have demonstrated that the majority of the alloys employed in the workshops are made using alluvial gold and electrum, generally containing PGE inclusions and small amounts of Cu.[4,19,27,29–32] In addition, the amounts of Ag in gold from Egyptian deposits were proven to match the composition of gilding foils from Middle Kingdom tombs excavated in the cemetery at Abydos.[33]

The alloys employed in the manufacture of the group of jewellery from tomb 124 at Riqqa are electrum alloys containing high Ag contents and rather low Cu contents (between 1 and 3 wt%). Similar to other Middle Kingdom objects in the collection of the Ashmolean Museum,[26] the winged beetle pendant and the god Min amulet contain Ag amounts that almost reach 50 wt%. Gold from Egyptian Eastern desert deposits typically contains amounts of Ag that range from 20 to 30 wt%.[34] Despite the composition of several objects considered in this work lie outside of this range, Ag contents may attain about 55 wt% in gold grains[35] at a few Egyptian mining regions, like the mines at Wadi Hammad,[36] Atud,[37] Um Samiuki,[38] and Abu Swayel.[39]

A small number of PGE inclusions (Figure 8) were identified on the surface of the winged beetle pendant and the pectoral, consistent with the use of alluvial gold.[19,40] Table 5 provides the data obtained by EDS for

TABLE 5 Elemental composition obtained by EDS for the two analysed PGE inclusions identified at the surface of the winged beetle and the pectoral from tomb 124, normalised to 100 wt%. Note: n.d. stands for not determined

	In wt%		
Location of PGE	**Os (L_α)**	**Ir (L_α)**	**Ru (L_α)**
Winged beetle (MM 5967)			
PGE 1, sp1	26	48	25
PGE 1, sp2	28	47	25
Pectoral (MM 5966)			
PGE 2, sp1	23	77	n.d.
PGE 2, sp2	22	78	n.d.

the two inclusions analysed, showing that one is an Os-Ir-Ru alloy and the other one is an Ir-Ru alloy. Figure 9 compares the two PGE inclusions analysed in the objects from tomb 124 with the inclusions analysed in New Kingdom objects excavated at Riqqa, those from tomb 296 and two penannular earrings in the collection of the MM.[4] The composition of the inclusions was found to be quite variable, sometimes within the same item and containing levels of Ru below and above the 25 wt% suggested for the gold from the Middle Kingdom onwards.[31]

4 | COMPARISON OF JEWELLERY FROM NK TOMB 296 AND MK TOMB 124

The jewellery groups from Middle Kingdom tomb 124 and New Kingdom tomb 296 found at Riqqa provide a unique opportunity to compare the work of the Egyptian goldsmiths in one location at different periods. The two groups of objects exhibit the use of different technologies; although the jewellery from tomb 124 is very polychrome, made from supports in whitish gold alloys inlaid

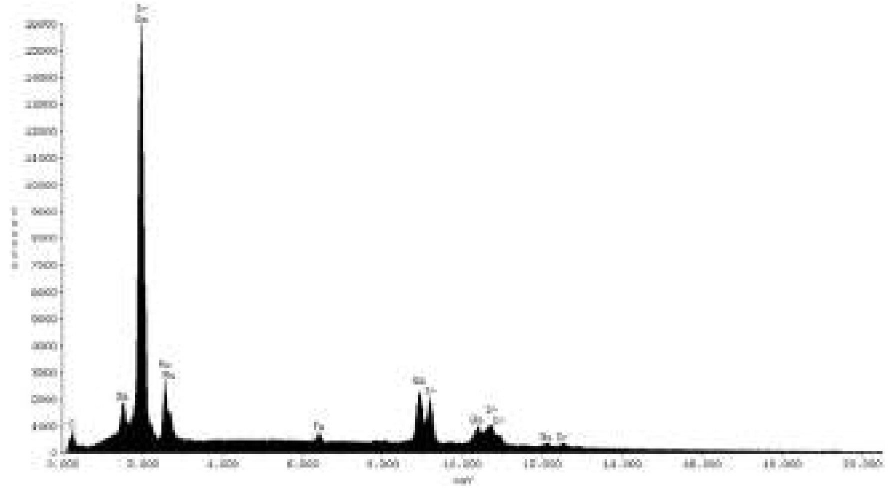

FIGURE 8 EDS spectra of an Os-Ir-Ru alloy PGE inclusion

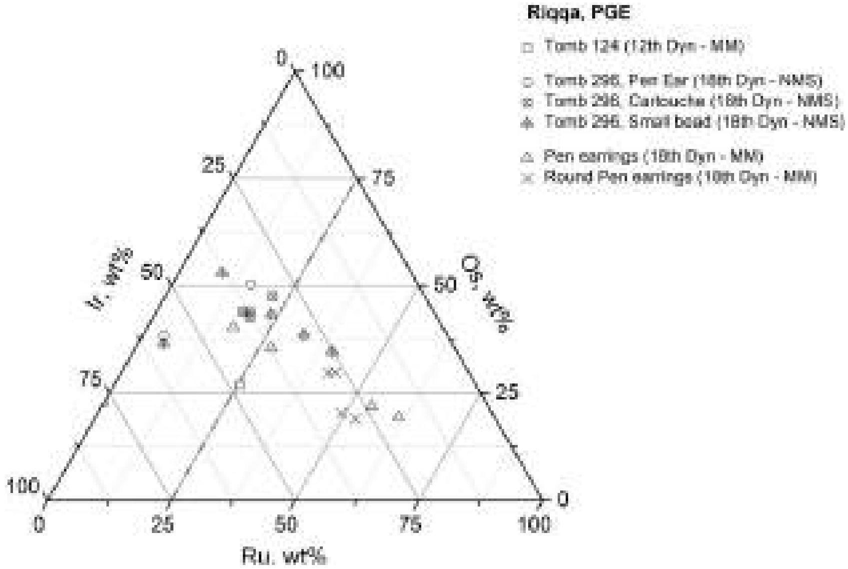

FIGURE 9 Ternary Ru-Os-Ir diagram (in wt%) showing the average composition of the PGE inclusions characterised by EDS analysis in the Riqqa jewellery (these results should be regarded as semiquantitative due to the geometry of the inclusions and the lack of comparative analytical standards)

with colourful materials, the penannular earrings and necklace beads and amulets from tomb 296 are made from joining hammered sheets made from yellowish gold alloys.[4] The shell pendant from tomb 124 is the only item decorated with a granulation and filigree pattern, and it is thus different from all the other objects.

For the construction of the jewellery from tomb 296, hard-soldering was the process extensively used to join the parts, using solder alloys made by addition of Cu to the base gold alloys.[4] The morphology of the ancient joins in all the objects from tomb 124 similarly revealed the use of hard-soldering. EDS analysis of a few pectoral joins confirmed the addition of Cu to the base gold alloy to produce the solder alloys.

In Figure 10, the Ag and Cu contents determined for the two groups of jewellery were plotted. The jewellery from tomb 124 contains 25–50 wt% Ag and seems to a certain extent to correspond to alloys that are represented

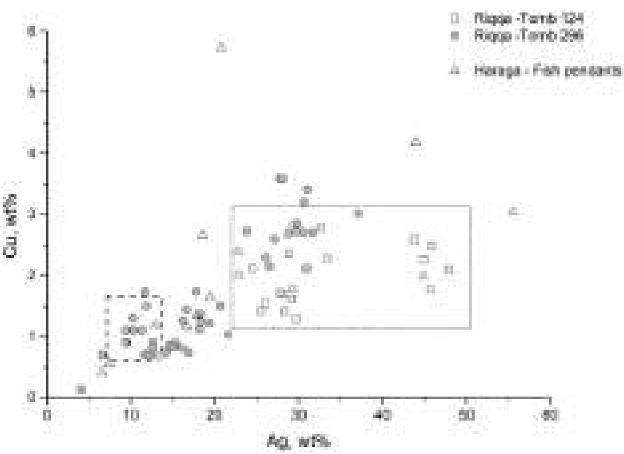

FIGURE 10 Ag and Cu contents (in wt%) obtained by p-XRF for the jewellery from tomb 124 compared with the jewellery for tomb 296[4] and fish-pendants from Haraga[27]

in Middle Kingdom items, like those from tomb 72 excavated in the Haraga cemetery produced using alloys containing 5–40 wt%,[27] and those published by A. Lucas containing 3–22 wt% Ag.[28] For comparison, the compositions of the typical Middle Kingdom fish-pendants found at Haraga were plotted in Figure 10. The large group of Egyptian items in the collection of the Ashmolean Museum analysed by Gale and Stos Gale[41] also revealed the use of those types of alloys. Interestingly, the majority of the objects produced up until the Second Intermediate Period, which also exhibit more than 40 wt% Ag, are attributed to the Middle Kingdom.

In comparison, the only type of alloy that is not observed for tomb 296 is the whitish gold with high silver levels. However, the penannular earrings from other 18th Dynasty tombs at Riqqa contain about 48 wt% Ag[4] and a few silver-rich electrum items have been reported in other burials, like the girdle from the Second Intermediate Period Qurna burial,[19] one bivalve shell and one uraeus pendant from the 18th Dynasty tomb of the three foreign wives of King Tuthmosis III,[42] and some foils from the 18th Dynasty tomb of Yuya and Tjuiu.[43]

If the use of Ag-rich electrum seems recurrent in Ancient Egypt until the New Kingdom, its origin still remains to be explained. It has been suggested that aurian silver might have occurred naturally in primary gold and primary silver deposits,[44] even if a nonlocal origin cannot be ruled out.[45]

A last point of note, high-purity gold alloys observed in tomb 296 that are absent from tomb 124, could be characterised in several Middle Kingdom items, such as those from tomb 72 at Haraga and from several tombs at Abydos.[33] The penannular earrings from tomb 296 were made with alloys containing about 10 wt% Ag and the necklace beads with variable alloys with Ag amounts ranging from 5 up to 20 wt%. High-purity gold alloys were found in a few New Kingdom items in the collections of the Ashmolean Museum,[26] of the Louvre Museum,[35] and of the National Museum Scotland,[13] as well as from the tombs of Yuya and Tjuiu[28,43] and King Tutankhamun.[46,47] The high-purity gold observed for tomb 296 could correspond to the suggested 18th Dynasty change of gold supplies based on the representation of gold dust and cast rings in wall-paintings.[29]

5 | CONCLUSION

The jewellery group from tomb 124 excavated in Riqqa was heavily restored in the past. The restoration processes employed are variable, from simple surface cleaning to addition of parts. Despite being highly restored and tarnished, this group of jewellery revealed new information about Ancient Egyptian goldsmithing. Most of the objects exhibit the use of hammering, chasing, and joining, together with typical cloisonné work inlaid with light blue-green turquoise, red carnelian, and dark blue lapis lazuli. In particular, the shell pendant, decorated with filigree and granulation, is one of the earliest examples of the use of these techniques in Egypt, which became common from the New Kingdom onwards.

Silver-rich alluvial gold containing 25–50 wt% Ag and PGE inclusions was found to be predominantly used in the jewellery from tomb 124. In comparison, the jewellery items from tomb 296 contain 5–20 wt% Ag. These results might only be representative of those tombs and cannot be generalised for the periods concerned. Indeed, both high-purity gold and silver-rich electrum were characterised in the same Middle Kingdom burial at Haraga[27] and silver-rich electrum, which seems recurrent in Ancient Egypt until the New Kingdom, has been observed in jewellery and foils in several New Kingdom tombs.[42,43]

Therefore, at Riqqa, there is a preference for the use of whitish and pale-yellow gold alloys in tomb 124, and tomb 296 contains mainly items made with yellow and green yellow gold. As the gold from the Eastern Desert contains in general 20–30 wt% Ag and the gold from Nubia contains lower than 20 wt% Ag,[34] it is difficult to suggest whether the colour of the alloys reflects access to specific gold supplies or an aesthetic choice.

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