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The 17th Dynasty gold necklace from Qurneh, Egypt

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Abstract: In 1908, the archaeologist Flinders Petrie discovered a rich intact burial of an adult and child at Qurneh, near Luxor. Stylistically, the burial has been dated to the late 17th Dynasty, in the 16th century BC. The complete burial group came to Edinburgh in 1909.
A recent examination of the rings of the necklace found with the adult burial is presented as part of a wider study of the mummy collections of the National Museums Scotland (NMS). The necklace shows sophisticated workmanship, with 1,699 rings threaded onto four strands, the rings having uniform diameter and thickness, and very few of them showing any visible joints.
The necklace rings have been examined by Optical Microscopy, X-radiography, Scanning Electron Microscopy with Energy Dispersive X-ray analysis (SEM-EDS), air-path X-ray Fluorescence (XRF), and proton induced X-ray analysis (micro-PIXE). We summarise these findings and propose the method of manufacture. We also describe an experimental attempt to make joint-less rings in order to compare them with the originals.

Résumé : *En 1908, l'archéologue Flinders Petrie découvre à Qurneh, près de Louxor, sur la route de la Vallée des Rois, la tombe intacte et richement pourvue d'un adulte et d'un enfant. L'ensemble de la tombe a été stylistiquement daté de la fin de la XVIIe dynastie, XVIe siècle av. J.-C., et son contenu fut transféré à Edimbourg en 1909.*
Dans le cadre d'un projet de recherche sur la collection des momies égyptiennes du Musée National d'Écosse (NMS), le collier trouvé associé à l'adulte a été étudié. Ce collier se compose de 1 699 anneaux enfilés sur quatre rangs, chaque anneau présentant une section circulaire très uniforme avec très peu de joints apparents. Comment ses anneaux ont-ils été réalisés ?
Le collier a été analysé par microscopie optique, radiographie de rayons X, Microscopie Électronique à Balayage couplée à un système d'énergie dispersive de rayons X (MEB-EDS), Fluorescence de rayons X (FX) et analyse par faisceaux d'ions (micro-PIXE). Les résultats de cette étude sont présentés et discutés en parallèle avec les résultats d'un travail de recréation expérimental, visant à réaliser des anneaux sans joints apparents.

Keywords: Qurneh**,** mummy, necklace, rings manufacture, analysis.

Mots-clés : *Qurneh**,** momie, collier, manufacture anneaux, analyse.*

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1. Introduction

The NMS Mummy Project

National Museums Scotland (NMS) has extensive Ancient Egypt collections. They were mainly assembled from 1819 until the early 20th century, and include eleven mummies, over sixty (more or less fragmentary) decorated coffins, mummy-boards and masks, and a great number of associated burial goods (Dodson and Manley, 2010). The NMS Mummy Project was initiated in order to raise professional and public understanding about the people whose bodies and belongings had been preserved with such care. Individual mummies and coffins have been examined in a programme of whole body and dental X-radiography, CT-scanning, and material analysis and identification (Eremin *et al.*, 2000; MacLeod *et al.*, 2000; Buckley and Evershed, 2001; Manley *et al.*, 2002).

Perhaps the greatest treasure of the NMS Ancient Egypt collections is the intact burial of an adult and child in a simple pit-grave at Qurneh, near Thebes (modern Luxor), discovered and excavated by Flinders Petrie on 30 December 1908 (Petrie, personal diaries). Petrie sent the entire contents of the burial to the Royal Scottish Museum (a forerunner of NMS) the following year. The grave itself was on the way to the ancient cemetery at the Valley of the Kings, an area containing the tombs of several kings and queens of the 17th Dynasty. The burial was centred on a large anthropomorphic coffin with feathered decoration, painted dark blue, and gilded. The fine decoration on the coffin (generally known as *rishi*, from the Arabic for 'feathered', ريش) was a Theban innovation dating from the 17th Dynasty, i.e. the early or mid-16th century BC (Miniaci, 2007), surpassed only by those of two 17th Dynasty kings discovered near Qurneh. Only the coffins of two Theban queens from the early 18th Dynasty, i.e. the late 16th century BC, are larger. Therefore, dating the coffin to the 16th century BC seems straightforward, and other elements of the burial, such as the ceramics, tend to confirm this.

The *rishi*-coffin contained the mummy of a young adult female, unwrapped by Petrie at the time of discovery and now complete, but disarticulated. The grave goods included furniture, ceramics, food-offerings, a sceptre, an inlaid headrest, a decorated oil-horn, and jewellery. A simpler chest-shaped coffin containing the remains of a young child was also unwrapped by Petrie. The wealth of the burial is evident from the jewellery found with both mummies, which Petrie described as "*the largest group of goldwork that had left Egypt*" (Petrie, 1932). This wealth is remarkable considering that Egypt was politically divided, and the kings at Thebes had no direct access to the wealthy trade routes of the Mediterranean, nor to the gold-rich mines of Nubia. Even the burials of kings of this period were quite simple. The most obvious explanation is that the occupants were members of the 17th Dynasty royal family at Thebes, which would certainly accord with the location of the tomb at Qurneh (Eremin *et al.*, 2000; Roehrig, 2007).

Nevertheless, the woman's specific identity remains a mystery, and none of the studies carried out so far have allowed us to establish whether the child and adult woman were related, although that would be what we may expect of a shared burial in Ancient Egypt. We have not yet undertaken DNA analysis of the human remains, but have concentrated on studying the grave goods, particularly the jewellery, to see what these could reveal.

The jewellery is described in Petrie (1909) and Eremin *et al.* (2000). Both the adult and child had necklaces and earrings: in this study, we concentrate on the adult necklace (NMS A.1909.527.19, Fig. 1a), but refer also to some shared similarities with the child's earrings (NMS A.1909.527.43).

The Gold Necklace

The style of the necklace is straightforward: a large number of gold rings strung together to form four decorative bands that combine into each side of a clasp (Fig. 1), the two halves of which are made from four groups of eight

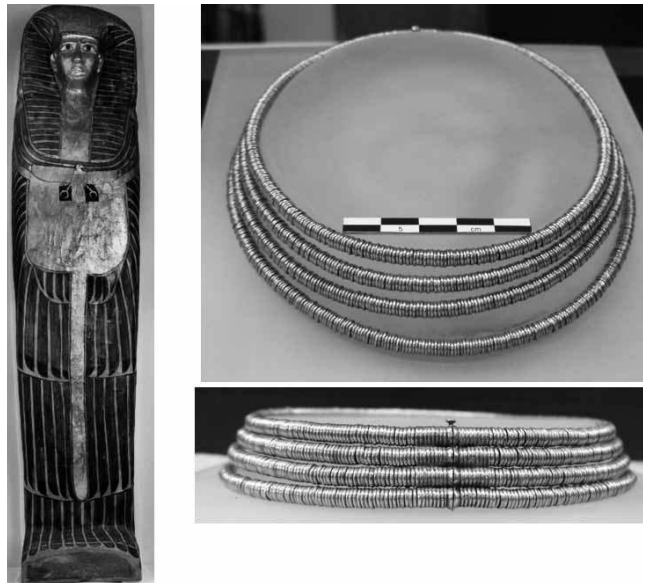

Figure 1: (See colour plate) Coffin of the adult woman and necklace showing clasp and pin.
Figure 1 : (Voir planche couleur) Cercueil de la femme adulte et collier illustrant le fermoir et l'épingle.

rings fused together. The necklace is closed by fitting the two parts of the clasp tightly together and inserting a short gold pin through the centre of four overlapping gold loops from either side. Only a small number of necklaces of this type and date are known from museum collections (Roehrig, 2007; Binder, 2008).

Petrie noted that the rings were "*thick enough not to collapse when squeezed between the fingers*" (Petrie, 1909). He measured and weighed them and counted 1,653 rings. A re-count carried out during conservation works in 2006 increased the number to 1,699 (Melville, pers. comm.), possibly by including some of the fused rings from the clasp. There is no record of any additional rings being found and added to the necklace, although Petrie did re-string it because "*a very thick pack of fibre filled the rings; so compact that only two rings could be dragged off at a time*" (Petrie, 1909).

The rings are full rings, that is to say the vast majority are not open, like many of the rings making up parts of other Egyptian jewellery, including a smaller necklace found with the child burial (NMS A.1909.527.11). Petrie stated that "*each has been soldered to join it*" (Petrie, 1909), but in fact only a very small number of them show external marks that clearly support this statement.

2. Methods

Technical examination

Optical and SEM imaging using both secondary electron (SEI) and backscattered electron (BSE) detectors were used to examine the surface appearance and details. The SEM was a Camscan MX2500 operated in both high vacuum and controlled pressure mode. We focused on three of the rings removed during conservation, which were placed on a standard SEM stub and imaged directly. The composition was determined using a ThermoNoran Vantage Energy Dispersive (EDS) system (recognising the possibility of slight surface enrichment of gold from the bulk composition).

X-radiography was used under various experimental conditions to look for seams or joints. The three rings were analysed along with two earrings from the child burial and other gold jewellery items by XRF and PIXE (see Troalen *et al.*, 2009). The XRF system is an air-path Oxford ED2000SW instrument configured to provide a collimated X-ray beam of 1.5x2 mm at the object, the precise spot identified by crossed lasers and using XpertEase fundamental parameters analysis calibrated against internal NMS laboratory gold/silver/copper standards (GCS5 and Rolled Gold). The PIXE[1] at C2RMF used 3 MeV protons (Dran *et al.*, 2004) and experimental conditions for gold (given in Guerra and Calligaro, 2004 and Guerra, 2004) calibrated with in-house gold/silver/copper standards Gold 6917 and the same NMS standards.

Methods used to make the rings

The question of how the rings were made was asked before it became possible to remove and examine some of the rings in technical detail. We commissioned experimental reconstructions from a modern goldsmith, reported here along with the subsequent technical examination.

Three methods that could have been used to make such uniform rings are:

– cutting wire segments to uniform lengths, looping into circles and soldering the joints;

– casting in a single or multiple ring mould;

– punching each ring individually.

The first method would require uniform lengths of wire, thin strips cut from a hammered sheet, or short cast-segments. Wire could also be made by strip- or block-twisting (there is no evidence of Egyptian drawn wire, Andrews, 1990), wound round a uniform diameter hard (bronze?) rod, and cut to produce a collection of open rings which could then be joined by diffusion bonding or soldering. For the former, a fine copper-rich powder (possibly with an organic glue) would be applied to a tight joint and strongly heated (Andrews, 1990; Ogden, 2000; Lilyquist, 2003). For the latter, a more open joint could be filled with a lower melting point alloy. Burnishing would hide any visual traces of the joint.

Casting would entail a precision two-part mould or a simpler open mould. More complicated lost-wax casting would entail the initial modelling of the rings in wax prior to encasing them in a clay mould, melting the wax, and filling the negative volume with molten gold alloy. Each method could theoretically produce individual rings or multiple groups of rings. Lost-wax cast rings would have no joint, but there would be a sprue; flash lines at the joints might show from two-part moulds.

Punching could be performed from a flat sheet or flattened blob of gold, drilling or punching a central hole which could be enlarged to produce rings with no joint. There are several images of craftsmen using single and multiple drills to bore holes in stone beads (Andrews, 1990).

1. Thanks to funding from EuArtech.

Before we were able to examine individual rings, we investigated the feasibility of punching and commissioned a modern gold worker (Ms Jacqueline Mina) to make 'joint-less' gold rings to look like those from the necklace. She made equal weight gold droplets, flattened them, and then formed a central hole with a series of steel punches, annealing the rings throughout to maintain workability. The intention was feasibility rather than reproduction, and the work used 24-carat gold, steel tools, and a gas flame, rather than more archaic materials.

3. Results

Examination of the necklace

The form of the rings was shown in optical and SEM images to be very regular (Fig. 2). The three rings examined individually measured between 4.2 and 4.5 mm external diameter, 0.8 mm thick, and with a 3.5 mm internal hole.

Each ring has a 'D' shaped section, so they were not cut from simple flat strips. The outer surface shows tool marks: fine parallel scratches running around the circumference, strong radial gouges, and areas of overlapping metal at the edges (Fig. 2d). We interpret the gouges as signs of the removal of metal using a very fine pointed chisel (the point around 10 microns across) before hammering the edges of the segment flat and smoothing and polishing. The inner surface of each ring is flat, but less smooth. There are no spiral lines from strip or block twisting, nor hammering marks on the flat inner surface, so the rings were not formed from round-section wire.

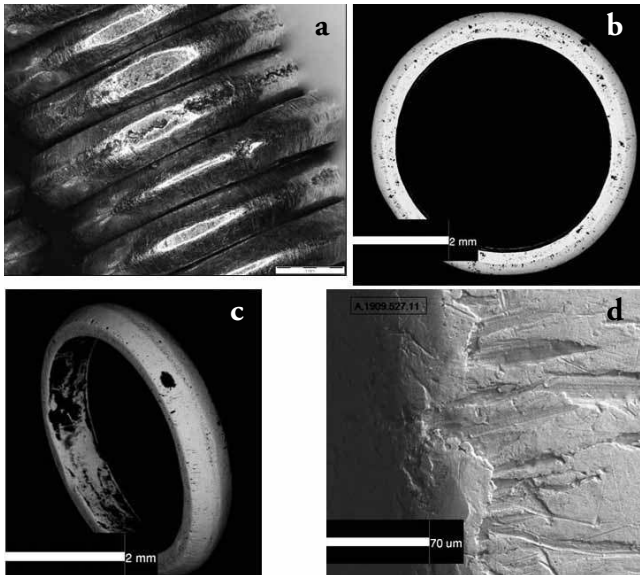

Figure 2: (a) Optical image of rings; (b), (c) & (d) SEM-BSE images showing dimensions and tool marks.
Figure 2 : (a) Images sous binoculaire des anneaux (b), (c) & (d) Images MEB-BSE montrant les dimensions et les marques d'outils.

There is no evidence of any flashing line on the inner surface, as expected from a two-part mould; instead, the only concentric internal line is slightly recessed. The rings are symmetric, and their regularity is inconsistent with being cast in an open mould. These observations confirm the assumption that they were not cast as complete rings.

The rough central band on the outer surface of the 'D' is similar to the inner surface of the ring: we interpret it as part of the original surface of the metal, which was cast as a wire segment into a 'D' shaped mould, the outer surface subsequently being worked to a smooth finish prior to looping each segment to form a ring.

However, optical and SEM examination and X-radiography failed to characterise the joints in the majority of the rings on the complete necklace. There are very few open rings, and some with joint-like marks, i.e. the metal is thinner, or thickens into a bulge (e.g., the 4th ring in Fig. 2a). These could be the result of poor casting or damage rather than fabrication.

The joint

The experimental reproduction demonstrated that it is perfectly possible to create joint-less rings, but that these did not match several of the features of the originals. It is evident from the SEM images (Fig. 3, a-f) that the punched rings are less uniform, and that the profile of the inner surface is quite different, having a raised inner ridge. While increased symmetry might come with practice, it seems unlikely that either the regularity or the flat, rather porous looking, inner surface of the originals could be achieved. We do not believe therefore that the rings were made using a punch.

Following the above examination and analysis, the more damaged of the three rings that had been removed was mounted and polished so that the existence or otherwise of a joint could be determined. The polished and etched ring is shown in Figure 4 (a and b), where the form of the joint is clear. The joint was made with added copper-rich solder (see below), the ends of the metal loop having been thinned to maintain the same thickness as the rest of the ring. The grain structure of the ring itself suggests working and annealing, while the solder shows a dendritic structure, similar to that shown in Scott and Doehne (1990).

The thickness, structure and composition of the joint confirm that it is the result of an added solder, not diffusion

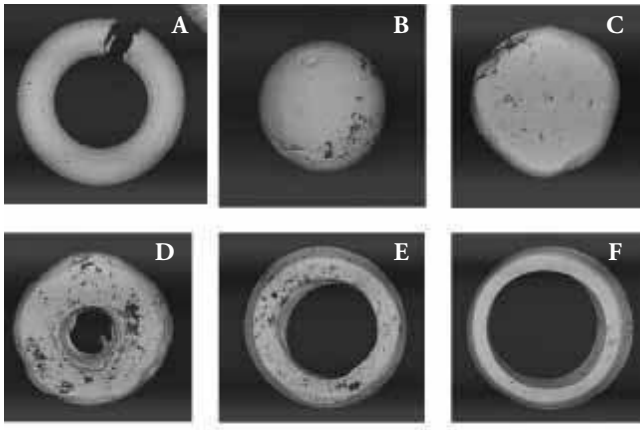

Figure 3: SEM-BSE images showing stages in the production of reproduction rings (ring diameter 5 mm).
Figure 3 : Images MEB-BSE illustrant les étapes de production des recréations des anneaux (diamètre des anneaux 5 mm).

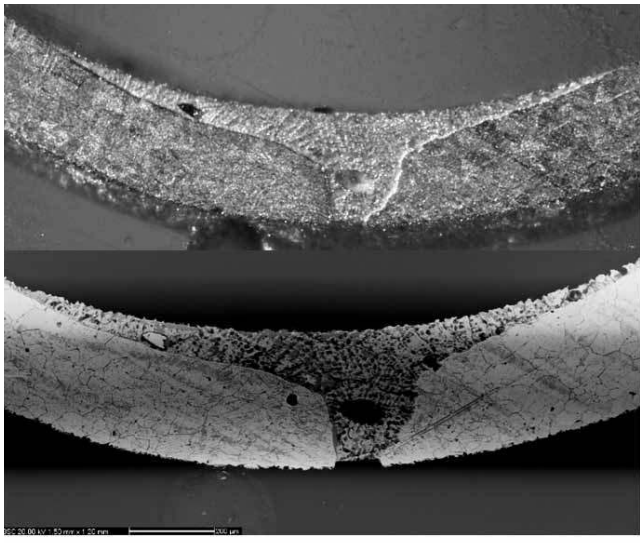

Figure 4: (See colour plate) (a) Optical and (b) SEM-BSE images of polished and aqua regia etched area of joint in ring. Scale bar is 200 microns.
Figure 4 : (Voir planche couleur) Images (a) sous binoculaire et (b) MEB-BSE de surfaces polies et attaquées à l'eau régal de la jointure de l'anneau. Barre de l'échelle 200 microns.

bonding. This use of hard soldering with addition of a distinct metal alloy is considered less common than diffusion bonding, but has been found occasionally on pieces from the ancient world (Lilyquist, 2003). Plotting the compositions on the Au-Ag-Cu ternary liquidus diagram provided by Scott and Doehne (1990) indicates a melting temperature of c. 950 °C for the solder, as opposed to just over 1000 °C for the ring, demonstrating a rigorous control of the temperatures during soldering.

Comparison with other necklaces

While there are many Egyptian gold necklaces from this period containing ring beads (as illustrated in Lilyquist, 2003), most appear to be square sectioned, often with quite clear (and open) joints. We have examined only two other necklaces of the 17th-18th Dynasty; one at the Metropolitan Museum, New York (Object 16.10.314) and one at the British Museum, London (inventory number EA 14693). Binder (2008) also refers to these necklaces and their distinct characteristics of the *shebu*-type. We are grateful for technical and analytical information regarding the necklaces in the Metropolitan and British Museum to Mark Wypyski and Deborah Schorsch from the Metropolitan Museum, and Nigel Meeks from the British Museum.

The Metropolitan necklace is 335 mm long, with approximately 450 ring beads, each 6 mm in diameter (Roehrig 2007). There are hemispherical end-caps, but no clasp. The ring widths vary, and clear joints are present, either square or chamfered. Some of the jointed areas appear as swellings, presumably where there is excessive solder or the metal has begun to melt (Fig. 6). The SEM-EDS analysis shows that the joints have a higher copper content than the rings (4%, as compared to around 2%). The rings have visible platinum group inclusions, but have a higher silver content than those from Qurneh (see below). The SEM examination shows some tool marks and a line around the circumference similar to the Qurneh rings, but the 'D' shaped cross-section of the outer side of the rings is less triangular.

The British Museum necklace has very finely finished rings with square joints. The clasp has a closing mechanism very similar to that from Qurneh. The rings lack visible PGE group inclusions and are of higher purity gold than those from Qurneh. There were no visible working marks or surface features similar to those seen on the other two necklaces.

Compositional analysis

The results of each of the experimental methods (Table 1) show that the Qurneh necklace, with its high percentage of gold (86-88%), silver (10-12%), and copper (2%), is in all probability made of alluvial gold. This is supported by the presence of inclusions of osmium-iridium-ruthenium (PGE group elements, Meeks and Tite, 1980; Ogden, 1976) on many of the rings (as well as on other pieces from the burial, see Troalen *et al.*, 2009).

A concern with any analysis of ancient gold is the extent of surface change, either deliberate or from corrosion during burial, a problem noted by Lilyquist (2003) for Egyptian

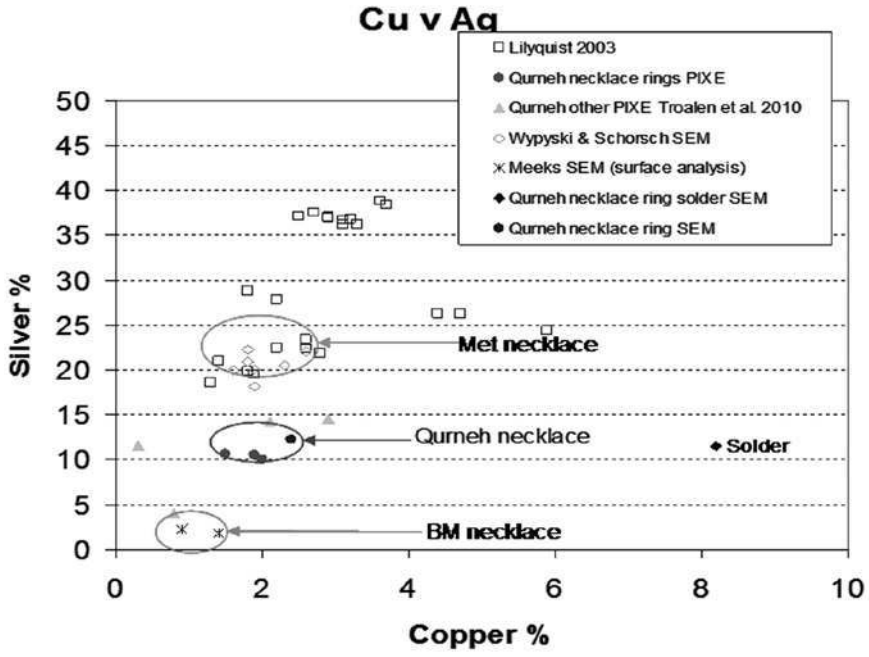

Figure 5: Compositions of the Qurneh gold, artefacts in Lilyquist (2003), and comparison of necklaces in the Metropolitan Museum of Art (courtesy of Mark Wypyski and Deborah Schorsch) and British Museum (courtesy of Nigel Meeks).
Figure 5 : Compositions des objets de Qurneh, des objets publiés par Lilyquist (2003), et comparaison des colliers du Metropolitan Museum of Art (courtoisie de Mark Wypyski et Deborah Schorsch) et du British Museum (courtoisie de Nigel Meeks).

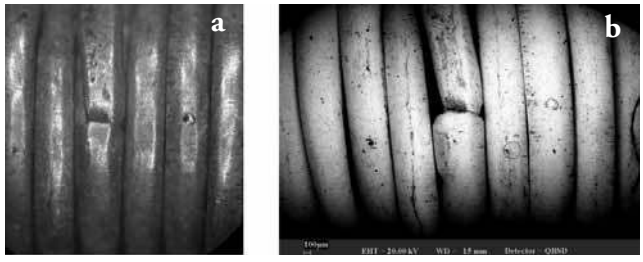

Figure 6: (See colour plate) Necklace 16.10.314 in the Metropolitan Museum of Art: (a) optical image; (b) SEM BSC image (Courtesy of Mark Wypyski).
Figure 6 : (Voir planche couleur) Collier 16.10.314 du Metropolitan Museum of Art: (a) image sous binoculaire (b) image MEB-BSC. (Courtoisie de Mark Wypyski).

gold. The polished section of the necklace ring allowed us to compare directly the surface- and core-gold compositions using SEM-EDS. A small compositional change was found, but the composition determined from the core metal in the section was very close to the PIXE and XRF results (see Table 1). Thus, while there may be some surface change resulting from the burial, it represents only a very thin layer which effects the SEM-EDS analysis, and the XRF and PIXE data are essentially corresponding to the bulk composition.

Figure 5 compares the Qurneh gold with the published analyses by Lilyquist (2003) for 'presumed ancient' material from the Metropolitan Museum collection, plus specific data from necklace (16.10.314)[2] and preliminary SEM-EDS surface analysis data from different areas on the British Museum necklace[3]. The alloy used for the adult's necklace and for other pieces from the Qurneh burial (summarised in Troalen *et al.*, 2009) is notably richer in gold and with a lower silver content than the majority of the comparable artefacts presented by Lilyquist (2003).

Finally, we compared the adult's necklace rings with the jewellery from the child's burial. The child's necklace differs significantly from the adult's, and resembles the small ring bead strings illustrated in Lilyquist (2003); the rings are smaller than those of the adult, uneven in width, and have open joints; they were clearly formed by rolling metal strips into circular loops. Their composition is also very different from the adult's necklace, with a high but variable silver content (see Troalen *et al.*, 2009). In contrast, the child's earrings resemble the rings of the adult's necklace more closely, being 'D' shaped in section, with radial tool marks and a flat inner surface. The alloy is also similar, but with slightly higher copper and silver contents (Table 1). While in no way conclusive, this aspect does tentatively support an association between the adult's and the child's burials.

2. Thanks to Mark Wypyski and Deborah Schorsch.
3. Thanks to Nigel Meeks.

Piece		Cu (wt%)	Au (wt%)	Ag (wt%)
Adult necklace rings 1-3: surface	XRF	1.6 sd 0.1	86.0 sd 0.2	12.0 sd 0.6
Adult necklace rings 1-3: surface	PIXE	1.8 sd 0.2	87.8 sd 0.2	10.4 sd 0.3
Child earring A	PIXE	2.9 sd 0.4	82.5 sd 0.5	14.6 sd 0.5
Child earring B	PIXE	2.1 sd 0.4	83.7 sd 1.2	14.2 sd 1.0
Adult rings 1&2: surface	SEM-EDS	1.1 sd 0.4	91.7 sd 1.5	7.2 sd 1.2
Adult ring 3: polished section	SEM-EDS	2.4 sd 0.2	85.5 sd 0.2	12.2 sd 0.4
Adult ring 3: polished solder	SEM-EDS	8.2 sd 0.3	80.4 sd 0.6	11.5 sd 0.3
Adult ring 3, area near joint	PIXE	4.0	86.8	9.1

Table 1: Summary of compositional data from different techniques for the three adult necklace rings and the two child earrings (sd is the standard deviation from a number of separate analyses and does not include calibration estimates or counting errors).
Tableau 1 : Les compositions obtenues par les différentes techniques pour les 3 anneaux du collier de l'adulte et pour les deux boucles d'oreille de l'enfant (sd représente l'écart-type d'analyses indépendantes et ne considère pas les mesures de calibration et les erreurs de comptage).

4. Conclusions

The rings of the necklace from the adult burial at Qurneh were most probably made from individual fragments of gold from an alluvial source cast into a 'D' shaped wire segments in an open mould, formed into rings, and joined using a metallic solder. Comparison of the surface and polished section of one ring confirmed the composition of the gold and provided clear evidence indicating that the surface composition of the necklace determined by PIXE and XRF is close to that of the bulk metal. Finally, SEM examination and PIXE analysis of the two damaged earrings from the child's burial have shown that these are similar in form and composition to the adult's necklace, adding to the likelihood that the two burials are associated.

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