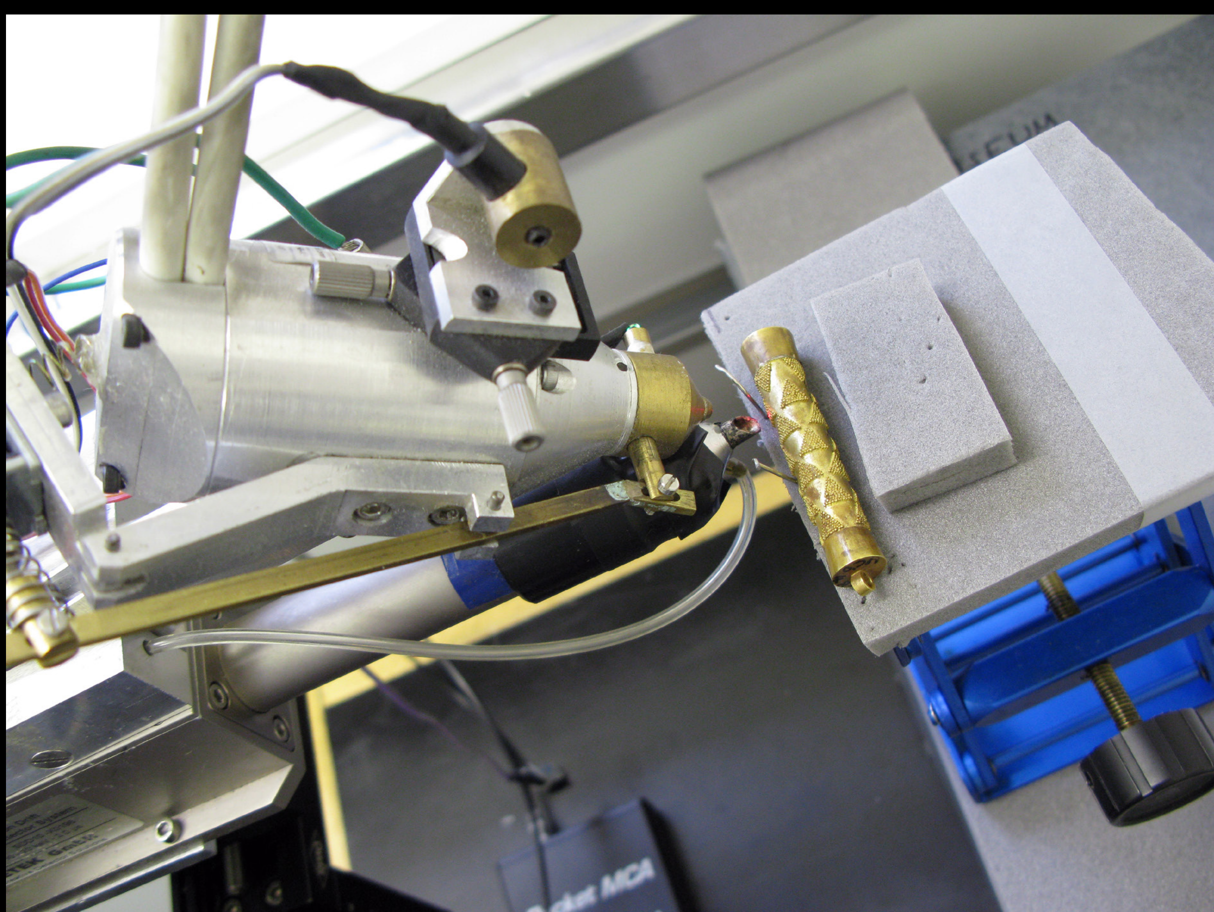
McDONALD INSTITUTE MONOGRAPHS

Ancient Egyptian gold

Archaeology and science in jewellery (3500–1000 BC)

Edited by Maria F. Guerra, Marcos Martinón-Torres & Stephen Quirke



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with contributions from
Wolfram Grajetzki, Maria F. Guerra, Marei Hacke, Mona Hess, Susan La Niece, Quentin Lemasson, Lindsay MacDonald, Margaret Maitland, Marcos Martinón-Torres, Nigel Meeks, Gianluca Miniaci, Brice Moignard, Jack Ogden, Claire Pacheco, Sandrine Pagès-Camagna, Laurent Pichon, Matthew Ponting, Campbell Price, Stephen Quirke, Martin Radtke, Uwe Reinholz, Ian Shaw, Jim Tate, Isabel Tissot & Lore Troalen

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On the front cover: *Analysis of the gold cylindrical amulet from Haraga at The Petrie Museum of Egyptian Archaeology (UC6482) using a portable XRF spectrometer*.
On the back cover: *Details under the SEM of the triangular designs of granulation on the tube of the cylindrical amulet from Haraga*.

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Editorial foreword

This volume aims to present a wide range of perspectives on early Egyptian goldwork, integrating the complementary yet distinct approaches of archaeology, materials science, jewellery and Egyptology. On one level, our primary task has been to present new analytical data on the manufacturing technology and elemental composition of dozens of artefacts preserved at six European museums. At the same time, we have sought to anchor and contextualize this new information based on current research from three perspectives: an introduction to the fundamental geochemistry and material properties of gold, a reanalysis of historical sources and of goldwork manufacturing-techniques, and a guide to the key analytical techniques employed. In this way, we wish to ensure that the volume is accessible to specialists and students from different backgrounds. We anticipate that this body of material will provide a rich source of information for further interrogation and discussion in the future, and our concluding chapter offers a first synthesis of some key points emerging from this new research. There we focus particularly on the findings that seem to us most significant, alongside open questions and suggestions for future work. In so doing, we explicitly highlight some of the many strands beyond the scope of the work presented here, hoping that they may provide pointers for others. We emphasize that the volume is addressed not only to those interested in the archaeology of Egypt in the timespan covered, but equally to scholars researching past technologies and archaeological goldwork elsewhere, who may find technical observations of broader scope that could prompt cross-cultural comparisons.

In spite of the substantial amount of data compiled here for the first time, it is important to remind ourselves of some potential biases that are inherent to this work and may thus skew our interpretations. The most important of these concerns the selection of objects. This project starts and, in many ways, remains throughout its course with the exceptional group of gold jewellery buried in Qurna, on the west bank of Thebes in Upper Egypt, with a woman and child whose names are unknown to us, at some point in the 17th or 16th century BC. Today the Qurna group is the most important Egyptian assemblage in the National Museum of Scotland, Edinburgh. In 2008, curator Bill Manley with materials scientists Jim Tate, Lore Troalen and Maria Filomena Guerra launched a programme of new analyses of the goldwork from the group. Already in this first investigation, the scope extended to comparison with jewellery from the preceding and following centuries (Tate et al. 2009; Troalen et al. 2009). With funding obtained from the CNRS, Guerra could then expand the range of collections involved in collaboration with Thilo Rehren at UCL, to include the UCL Petrie Museum of Egyptian Archaeology and the UCL Institute of Archaeology with its laboratory facilities, as well as the National Museums of Scotland and the British Museum as project partners (CNRS project PICS 5995 EBAJ-Au). On the initiative of Jim Tate, contact had been established already with colleagues Matthew Ponting and Ian Shaw at the University of Liverpool. As a result, the Garstang Museum is also participant in the wider project, together with the Manchester Museum, through the support of curator Campbell Price, and the Louvre Museum, through the support of curator Hélène Guichard and the late Sandrine Pagès-Camagna, material scientist at C2RMF (Centre de Recherche et de Restauration des Musées de France). We wish to emphasize here the fundamental role of Sandrine Pagès-Camagna in crucial stages of the project; without her participation the project could not have achieved a significant part of its aims – notably comparison between the Qurna group and the nearest securely dated examples of royal goldwork from the reigns of kings Kamose and Ahmose.

Other institutions participated with the provision of access to particularly specialized equipment: AGLAE facilities at C2RMF, Bundesanstalt für Materialforschung und –prüfung, and LIBPhys at NOVA University of Lisbon

With this new support, the research agenda was able to grow organically, adapting to fresh questions emerging from preliminary results, while contingent on the artefacts present in museums that were accessible to the project. Indeed, the history of the collections has been a significant factor, both enabling and constraining our research. The Louvre collections contain a range of jewellery from early excavations in Thebes, including representative material from the late second millennium BC settlement Deir al-Madina, and major works from 16th century royal burials uncovered during fieldwork directed by Auguste Mariette. The British Museum and the other participating museums in England and Scotland also preserve a mixture of material from documented excavations and earlier undocumented collecting practice. Here colonial history frames the kinds of material available. During and after the full British military occupation of Egypt (1882–1922), the Antiquities Service of Egypt under French Directors permitted officially recognized institutions to excavate in Egypt and, in return for the enrichment of the Egyptian Museum Cairo, to take a share of finds from excavations. Following division of finds in Egypt, excavation funding bodies based at Liverpool (since 1903) and London (since 1882) distributed finds to dozens of sponsoring museums (Stevenson 2019). The university museums in Liverpool and London were among the major recipients of these finds, and also hold substantial excavation archives. The Qurna group itself and several other sets of jewellery analysed during the project are unusual examples of this pattern of dispersal, where the vast majority of items distributed belonged to the types of objects found in large numbers in fieldwork. The project was therefore able to investigate objects from a wide social spectrum, from palace production (Qurna group, Haraga fish and cylinder, items of kings Ahmose and Kamose from Thebes) to finds in cemeteries of regional rural towns and villages (Qau, Badari, Matmar). At the same time, in expanding the chronological scope of analyses forwards to the New Kingdom and back to the late prehistory of Egypt, the participating museums could not cover every social group for every period. Most notably, and perhaps surprisingly for those outside the museum circle, these collections hold none of the major goldwork from the age of the great pyramids, the mid-third millennium BC. At that period, the concentration of power at Memphis around kingship separates the royal court from the regions, and this is reflected in the tombs of the period and in the distribution of finds. Gold and gilt ornaments are more prominent in burials at the Memphite cemeteries: Giza and Saqqara. The single outstanding assemblage of Egyptian goldwork from the mid-third millennium BC is the unparalleled burial of material related to Hetepheres, mother of king Khufu; the finds are on display in the Egyptian Museum Cairo. Egyptologists from Cairo, Vienna, Boston, Hildesheim and Leipzig directed excavations at Giza; their museums received a share in finds (Manuelian 1999). The museums in our project, from Paris to Edinburgh,

Table 0.1. *Numbers of artefacts (museum inventory numbers) analysed by site and period.*

	Dyn 1-2	First IP	Middle Kingdom	Second IP(-Dyn18)	New Kingdom	?	Total
Memphis					2		**2**
Riqqa			4		7		**11**
Haraga			13 + 1?				**14**
Lahun			5				**5**
Ghurab					1		**1**
Sidmant			1		1		**2**
Amarna					8		**8**
Qau area		15		5			**20**
Abydos	4		2 + 2?	2		3	**13**
Naqada			2				**2**
Thebes			2	2 + 7?	4		**15**
*Qurna				12			**12**
Buhen			1				**1**
?		1	5	2	22		**30**
TOTAL	**4**	**16**	**36**	**30**	**45**	**3**	**136**

are not on that distribution map. With this and other lesser gaps, our sample, however extensive, cannot and does not claim to be random or representative of an underlying population of 'Egyptian goldwork'. On our chronological range from fourth to second millennia BC, there are peaks and troughs in the frequency of artefacts, and we encourage the reader to keep these in mind graphically, in order to assess our interpretations in context and to develop their own further research agendas (see Table 0.1).

Another delimiting factor in the selection of objects derives from our focus on technique, directing our attention predominantly to jewellery, rather than other gold elements such as the prominent use of sheets for gilding larger substrates of wood or plaster. Gold foils were included for comparative purposes, particularly in the investigation of composition, but to a lesser extent. Furthermore, within the rich repertoire of Egyptian gold jewellery, we took a particular interest in select assemblages, starting with the Qurna group itself, and within these certain specific features, such as the small beads found in the child's coffin and the adult's girdle. While these are fascinating manifestations of both technology and consumption, they are not necessarily representative of a broader corpus. We would also emphasize that we sought primarily artefacts with well-recorded archaeological contexts, as these evidently allow for more robust inferences, and provide the most secure foundations on which to build further research. Where the museums could provide access to material not from documented excavations, but acquired before 1970, we have included certain items if they helped to complete gaps in understanding, as a secondary circle of supplementary information. In each such case we have done our utmost to investigate their authenticity and source, but undeniably any interpretation based on an unprovenanced object will have to remain tentative. Indeed, one of our analytical investigations demonstrated the risks in building historical conclusions on material without documented excavation context; a gold shell inscribed with the name of king Taa, who reigned close in time to the Qurna group, presents disconcerting features more consistent with modern rather than with ancient manufacture.

A final and equally important constraint concerns the background and expertise of the editors and contributors to this volume. While together we span interdisciplinary breadth, and have found synergies in our research, inevitably there remain areas beyond our interests and access, and indeed beyond the time scope of the project. For example, our data may be used as a starting point to address issues of provenance, but targeted consideration of the extraction methods and possible geological sources of gold is not addressed in detail in this volume. Instead, much more emphasis has been placed on issues of technology, and the application of the results to a concluding interpretation of the Qurna group. We look forward to seeing how others may take up such topics, and feel sure that the woman and child of Qurna will continue to pose new questions.

Finally, for the opportunity to share our discussions and findings with a wider research audience, we would like to express our gratitude to the McDonald Institute for Archaeological Research for including this volume in its series.

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Chapter 4

Jewellery manufacture: an Egyptian quartet

Jack Ogden

Research in jewellery, both art-historical and technical, can enhance our understanding of connections and chronology. Here are discussed the four aspects of Egyptian gold working where questions are raised concerning cultural connections. These are wire, engraving, gold cladding, and enamel. Wire, one of the most basic of jewellery components, is made using different techniques; engraving appears, surprisingly, in designs on some early Egyptian gold objects; gold cladding was used to change the aesthetic appeal of objects; and enamel requires the use of particular technologies.

A century ago Flinders Petrie complained that 'Gold seems to blind the eyes of excavators to everything else, and is as detrimental to publication … as it is demoralizing to the workmen who find it' (Petrie 1927, 1). A far more recent British Egyptologist excavating in Egypt, when asked by the present author if he had found any gold jewellery, answered in words to the effect 'Thank God, no'. This attitude can stem from worries about security and unwanted publicity. Indeed, the lure of 'treasure' that draws in the crowds to exhibitions of ancient Egyptian jewellery in museums worldwide is almost the antithesis to sober archaeological practice. But jewellery cannot be ignored as an important category of artefact for study. Research in this field, both art-historical and technical, can enhance our understanding of connections and chronology.

The first to consider ancient Egyptian metals in detail died before his work was published. This was the metallurgist Major Herbert Garland, best known as Lawrence of Arabia's explosives expert. His posthumously published book *Ancient Egyptian Metallurgy* is missing the originally envisioned chapter on gold and silver because his notes on these metals were 'too scrappy to be of any real value' (Garland & Bannister 1927, Preface). Garland's contemporary Alfred Lucas, chemist at the Cairo Museum, dealt briefly with the conservation and composition of Egyptian gold jewellery, but despite his close familiarity with much of the jewellery in the museum, including Tutankhamun's, he commented little on its technology (Lucas 1924[1]: 59–66; Lucas & Harris 1962). The same year that Howard Carter discovered Tutankhamun's tomb, 1922, Caroline Ransom Williams, described as the first professionally trained woman Egyptologist in America, completed her exemplary catalogue of the ancient Egyptian jewellery that had been in the Henry Abbott collection prior to being purchased by the New York Historical Society in 1860 (Lesko 2004; Williams 1924). Williams was greatly aided by John Heins, a gold and silversmith in the Department of Fine Arts of Columbia University, and their research into Egyptian jewellery technology provides us with our earliest detailed study. At this same time in Egypt, Émile-Séraphin Vernier (1852–1927), expert on ancient jewellery for the Institut français d'archéologie orientale in Cairo, was publishing the three volumes of his catalogue of the jewellery in the Cairo Museum with many comments on construction (Vernier 1907; Vernier 1907–1927). Petrie must have had Williams' and Vernier's work in mind when he noted that the observation on methods of manufacture of jewellery was 'justly recognised now as a necessary part of any catalogue' (Petrie 1927, 1).

Petrie's words seem to have fallen on deaf ears because little was published on the subject of Egyptian jewellery technology in the 1930s–1950s. The resurgence of interest in ancient jewellery manufacture really only came after the mid-1960s and then mainly in the field of Classical jewellery. Noteworthy here was the work of Reynold Higgins, Herbert Hofmann and Patricia Davidson, and Andrew Oddy (Higgins 1961;

Hoffmann & Davidson 1965; Oddy 2004[2]). Since then, the study of ancient jewellery technology has grown. Cyril Aldred discussed Egyptian jewellery technology in the early 1970s, as did Carol Andrews almost two decades later, although neither in great depth (Aldred 1971; Andrews 1990). The present author has provided coverage of ancient jewellery technology in general and some summaries specific to Egyptian gold working (Ogden 1982, 1990/1, 1992, 2000, 2011). Other recent work includes the study of the jewellery of the wives of Thuthmosis III in the Metropolitan Museum of Art, New York, by Christine Lilyquist and her colleagues (2003), research on Egyptian jewellery in the National Museum of Scotland by Lore Troalen and others (2009), and analysis of Middle Kingdon and other gold by Isabel Tissot and others (2015).

It is not necessary here to provide a summary of the development of jewellery technology in Egypt, even if there were the space to do so. The basics of jewellery making in the ancient Old World in general have been covered in the works just mentioned and a wider study by the present author is in preparation. What can be looked at here are four aspects of Egyptian gold working where questions are raised concerning cultural connections. These are wire, engraving, gold cladding and enamel.

Wire

One of the most basic of jewellery components is wire, whether as applied filigree, chain or serving functional use in specific components such as attachment loops. Today most gold wire in jewellery is made by what is termed 'drawing', whereby a thin rod of gold is pulled through a series of holes of diminishing diameter in a steel plate – a draw plate. The gold is drawn out, made both thinner and longer. Drawing in this way has not been unequivocally identified on gold wires in Europe or the Near East world prior to about the 8th century AD and so the presence of drawn wire in gold objects purported to be earlier than this is usually taken as a near-certain indication of incorrect dating or forgery. As Petrie noted more than a century ago, 'Drawn wire has not been found in any ancient work' (Petrie 1910, 90). Drawn wire can usually be identified by the fine parallel striations that run along the length of the wire; the microscopic ridges and less commonly scratches caused by minute irregularities in the draw plate perforations. The more sophisticated the wire drawing equipment, the less prominent the surface striations. The drawing in Figure 4.1 show schematically how with wire drawing the gold is squeezed into a smaller diameter, compressing and elongating its whole structure.

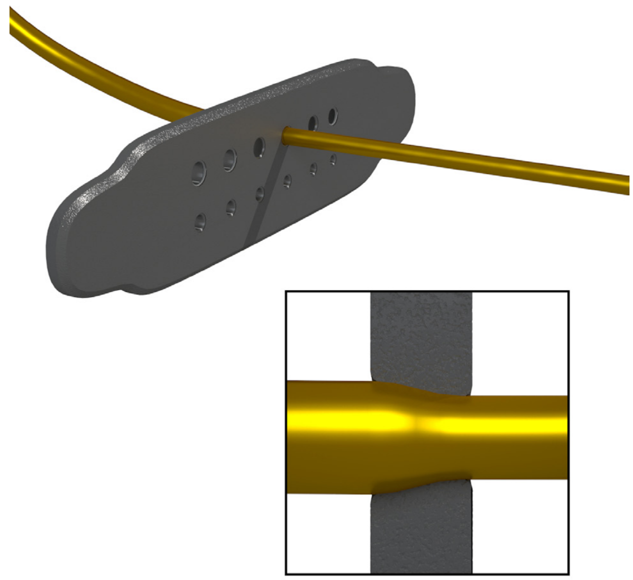

Figure 4.1. *Wire drawing showing how the wire is compressed and elongated by wire drawing.*

In antiquity, the most basic way to make a round-section wire in gold was to hammer a cut strip of gold to near-circular cross section. This technique was used throughout antiquity especially for larger diameter wires, such as those in some earring hoops. At the hands of a skilled craftsman, the resulting wires could be remarkably regular. Even so, cutting the initial strip of even, near-square cross section from gold sheet with a chisel or blade was not easy. One way round this was to cut a thinner, wider strip and fold this in half along its length before hammering or burnishing this to compact it into a regular section wire. This mode of manufacture, however, could result in some delamination. An early example of this is seen in a bracelet in the British Museum (EA 62468), dating to the First Intermediate Period and excavated at Mostagedda (Fig. 4.2; Brunton 1937, 101–2, pl. LXVII, no. 3). It was found on a woman's wrist. This takes the form of two wire hoops joined as a knot at the front. Carol Andrews noted that 'The break in the wire shows that a flattened cavity is present in the centre. Two seams are visible on the surface'. (Andrews 1981, 49, no. 276). This break, shown in Figure 4.3, reveals delamination and the likelihood that it is a hammered or burnished, folded strip.

For much of antiquity, round wires less than a millimetre or so in diameter were made by the so-called strip-twist technique. Here a strip of thin gold sheet is twisted and then rolled between two flat surfaces as shown in Figure 4.4. The resulting wire can be of very even cross-section and usually has 'seams' spiralling along the wire, visible to a greater or lesser degree. Strip-twist wire was widely distributed from Europe to the Far East prior to the introduction of true wire drawing. Some authorities have distinguished between strip- and block-twist wires (first perhaps Higgins 1969). The former made by twisting a thin strip, the latter by twisting a strip nearer to square in cross section. These do result in wires with slightly differing appearances, but to use different modern terms implies some deliberation on behalf of the original goldsmith, something I consider unwarranted here. Since the only difference is the width to thickness ratio of the initial strip, choice was probably fortuitous, the goldsmith working with the

Figure 4.2. *Gold bracelet from Mostagedda. First Intermediate Period. British Museum EA 62468.*

Figure 4.3. *Detail of the bracelet in Figure 4.2 showing break.*

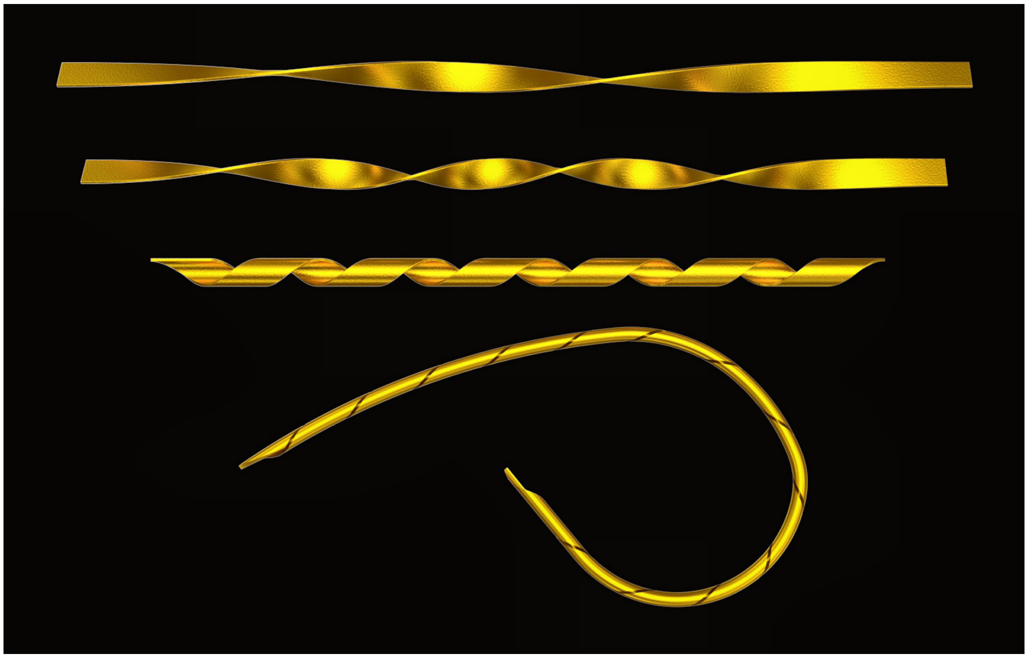

Figure 4.4. *The construction of strip-twist wire.*

gauge of gold his work demanded; there is no clear demarcation to justify separate terms (Ogden 1991).

The first to describe the strip-twist technique were Williams and Heins (Williams 1924, 39–44). They noted the spiral 'seam lines' on several examples of later Egyptian jewellery and illustrated Heins' replications of this wire type. Figure 4.5 shows wires with the characteristic spiral 'seam' of strip-twist wire on the handles of one of Tutankhamun's daggers. This is from a photo by William J. Young, formerly head of the Research Laboratory at the Museum of Fine Arts, Boston, taken at the time of the *Tutankhamun Treasures* exhibition at that museum in 1963. The presence of strip-twist wire on Tutankhamun's dagger does not prove that it was widely used in Egypt then since a foreign origin is often suggested for these daggers. However, wires that appear to have been made by the strip-twist process have been noted by Lore Troalen and her colleagues on Amarna Period jewellery in the collections of the National Museums Scotland (Troalen et al. 2009, 121). I have observed strip-twist wires on a pair of gold hair- or ear-rings of typical Tuthmoside type from Egypt and on a scaraboid swivel ring of New Kingdom Egyptian form, although found in Enkomi, Cyprus (British Museum 1897, 0401.276). We can ignore the strip-twist wire Cyril Aldred noted on an ear stud said to be from Amarna and of the New Kingdom because this is almost certainly of Ptolemaic date and is a fairly standard Classical Greek or Hellenistic type of ornament (Aldred 1971, 78, 209; Ogden 1990, 1, 177). Aldred said he knew of no pre-New Kingdom examples of strip-twist wire and Williams and Heins considered the technique to be 'late'. This is where the history of gold wire in Egypt begins to get intriguing.

We might expect strip-twist wire in Egyptian gold jewellery by the Middle Kingdom, because I have seen it in goldwork from Troy, from a century or two around 2000 BC, and in gold jewellery from

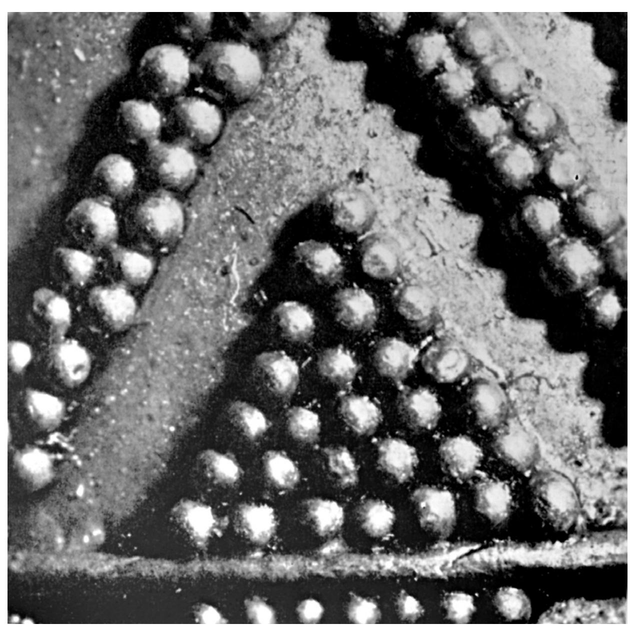

Figure 4.5. *Detail of the wire and granulation on one of Tutankhamun's daggers (18th Dynasty). Photo William J. Young, after Smith 1965, fig. 38.*

Figure 4.6. *Gold and lapis lazuli scarab ring (17th Dynasty). British Museum EA57698.*

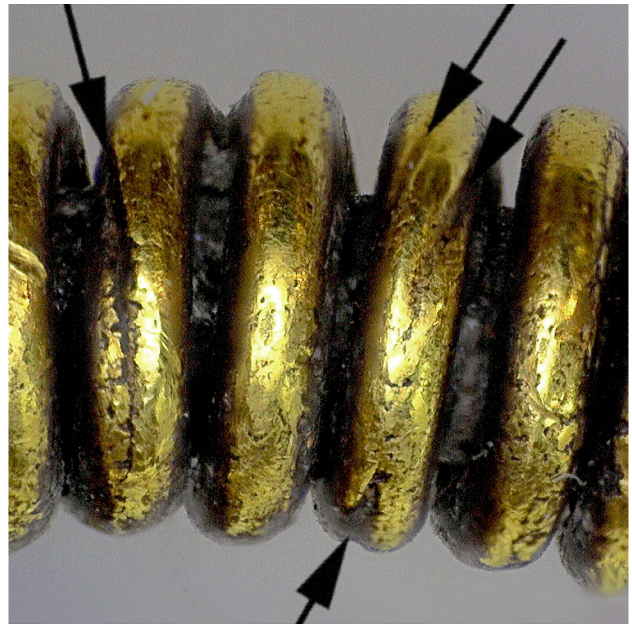

Figure 4.7. *Detail of the ring in Figure 4.6 showing the seams on the wire.*

Pre-Palatial Crete of about the same period. Indeed, there are gold wires in Egypt of pre-New Kingdom date with spiralling seams, but examination suggests that they may not all be strip-twist wire as we know it. An example is the wire on a 17th Dynasty gold ring set with a lapis lazuli scarab in the British Museum (EA57698; Fig. 4.6), recently studied by Gianluca Miniaci and his colleagues (Miniaci et al. 2013, fig. 2). Here the seams appear to be at a lesser angle than typically seen with strip-twist wires and in places are doubled and the direction of spiral is not consistent (Fig. 4.7). These are not characteristics expected with strip-twist wire.

To consider this puzzle, we need to go back to even earlier wires and to the first researchers to study them, again Williams and Heins. They showed that a strip of gold could be pulled through a perforation in a sheet of metal so that it was folded into a tube-like, reasonably compact, circular section wire (Williams 1924, 40). Hein's replication experiments demonstrated that wire produced by the 'strip drawing' technique could have almost straight or gently spiralling seams. Strip drawing is not true wire drawing in the modern sense because the strip is smoothed and bent into a round section (Fig. 4.8), not stretched out with significant distortion to the internal structure of the gold. More recently, Diane Lee Carroll and then Jamie Hall have carried our similar replication experiments with strip drawing. They found that no great force is needed and the wire can be pulled through holes in any suitable material, such as a copper-alloy plate held in the hands (Carroll 1970; 1972; Hall 2010). The wire so produced can have straight or gently winding 'seams', the latter caused by slightly twisting the strip as it is pulled, which facilitates the process. If the starting strip is nearer to square cross section, the process still works. The corners are rounded over and there can be multiple seams (or rather grooves) along the final wire, often gently spiralling, seemingly as in Figure 4.7. This is not drawing in the modern sense because the surface is just rounded and smoothed, and the process requires very little force; the internal structure is not stretched. A perforation in a stone

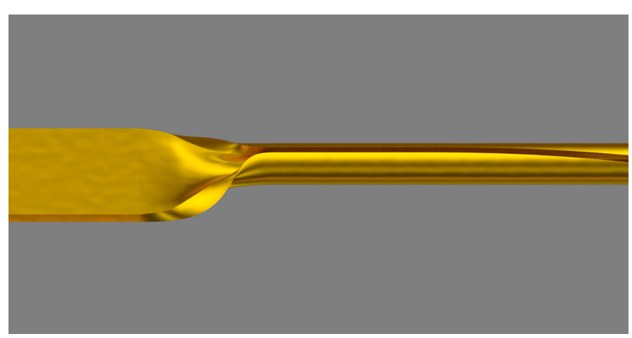

Figure 4.8. *Drawing showing how strip drawing curls a strip round into a circular section.*

bead would work equally well for strip drawing, but the gauge of ancient gold wire is usually far narrower than the holes in early stone beads.

The earliest example of strip-drawn wire cited by Williams and Heins was on the gold cover of a stone vessel from the 2nd Dynasty tomb of Khasekhemwy at Abydos and now in the Museum of Fine Arts in Boston (01.7287; Williams 1924, fig. xxii, A). This is thus securely dated to around 2700 BC. I recently examined the similar gold wires on two further jars from the Khasekhemwy tomb, which are in the British Museum (EA35567 and EA35568). One is shown in Figure 4.9 with a detail in Figure 4.10. As can be seen, the covers of these vessels are held in place by a binding made from pairs of wires twisted together to provide what is termed a rope. The binding on each cover was made from two such lengths of wire, doubled back on themselves, looped together and then twisted. They pass twice round the cover and the four wire ends are twisted together. The clay seal on these ends only survives on one jar (EA35567) and part of this, the twisted wires and the way the wires

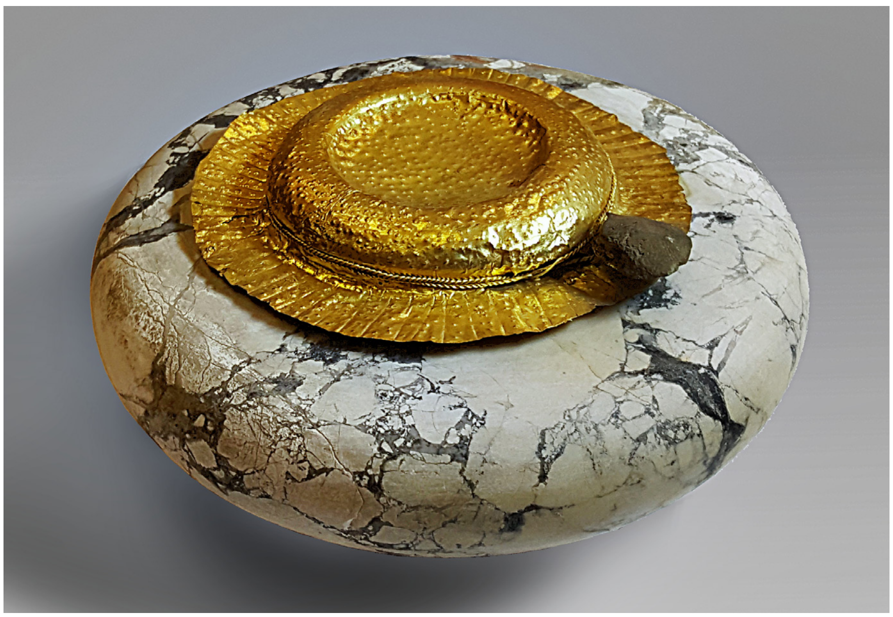

Figure 4.9. *Magnesite jar with gold lid. From the tomb of Khasekhemy at Abydos, 2nd Dynasty. British Museum EA35567.*

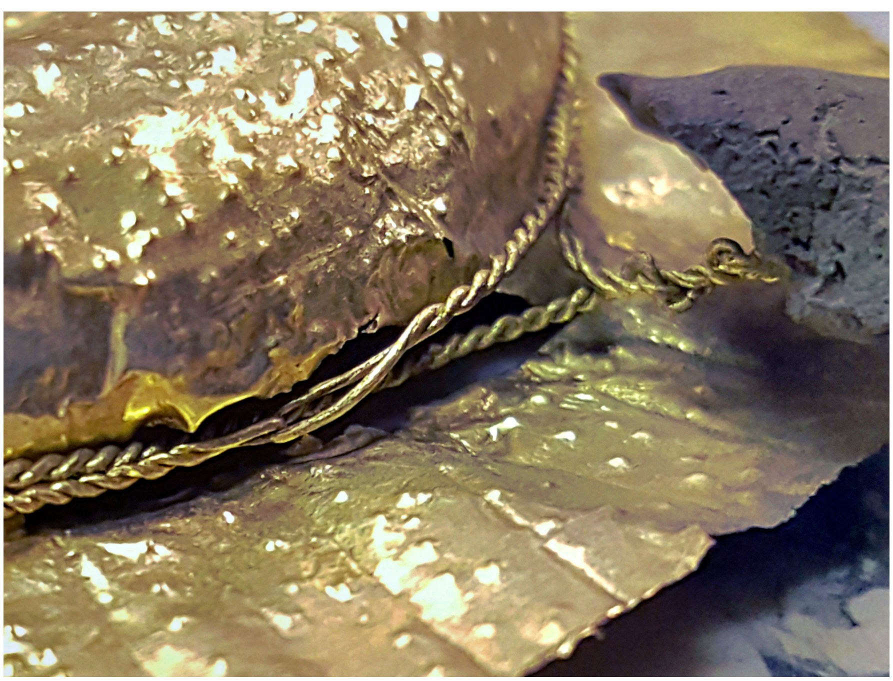

Figure 4.10. *Detail of the gold lid and binding wire on the jar in Figure 4.9.*

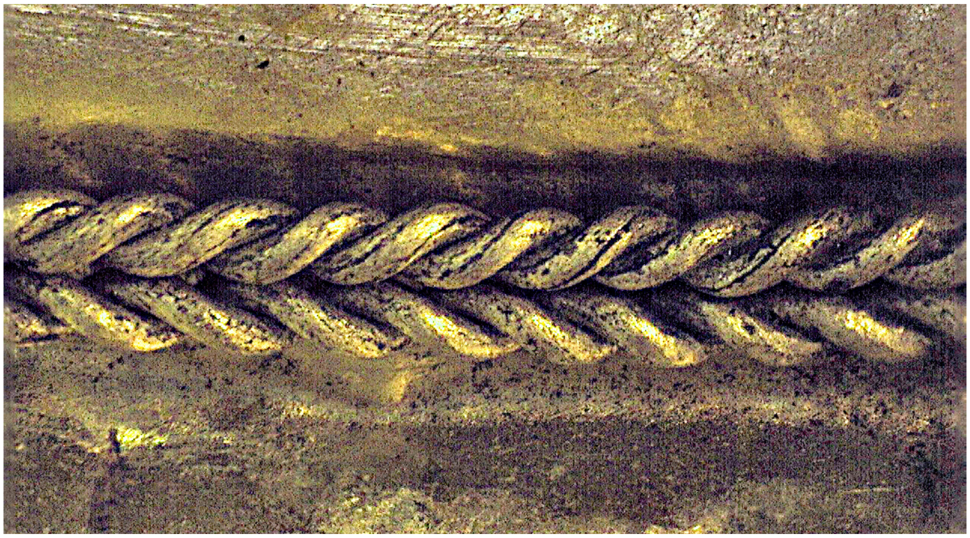

Figure 4.11. *Detail of the twisted wire 'ropes' on the jar in Figure 4.9.*

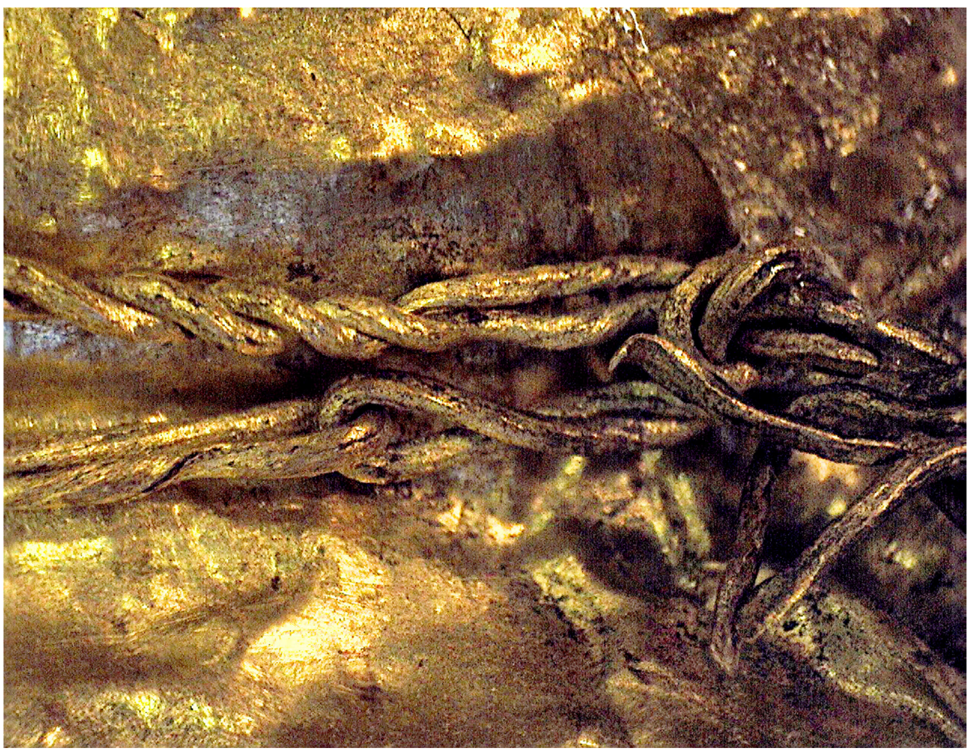

Figure 4.12. *Detail of the wires on the jar in Figure 4.9.*

were looped together as can be seen in Figure 4.10. The wires had to be looped together before they were twisted. They were twisted into ropes with different direction of twist, which provides an attractive herringbone appearance where the two ropes run parallel, as in Figure 4.11, a detail of EA35567. This reversing of twist direction seems to have been a deliberate aesthetic choice since it is seen in the Boston and two British Museum examples. The wires here are about 0.35 mm diameter and have seams, often multiple seams, which run essentially straight along the wire. The wires on the second British Museum jar (EA 35568) are about 0.4 mm in diameter and have one or more longitudinal seams. In one place (lower left of Fig. 4.12) a seam spirals quite steeply, in another it is almost straight (half way up on right in Fig. 4.12) but this variation is due in part to distortion when the wire was bent back and twisted. The wires on the two British Museum jars look the same as those on the Boston jar as illustrated by Williams and Heins.

The presence of seams that go along the length of the wire, as in Figure 4.11, can sometimes resemble the longitudinal lines on modern drawn wires, as Carroll noted, and this might explain why several early observers were convinced that the early Egyptians were familiar with true wire drawing. One such was Vernier who concluded that it was 'certain and evident that the Egyptians employed wire drawing from a very ancient period' (Vernier 1916, 40–2). The same year that Vernier made that statement, the Metropolitan Museum of Art, New York's excavation at Lisht in Egypt were published (Mace et al. 1916). The expedition had discovered the late 12th to early 13th Dynasty tomb of Senebtysy, a woman of high status and, as was usual in those days, the Museum received a division of the finds. One of these was a remarkable gold diadem, which contains in excess of six metres of round wire (Metropolitan Museum of Art 07.227.6; Fig. 4.13). The original excavation report refers to the diadem as being 'of three independent sections of beaten gold wire' (Mace et al. 1916, 58). The diadem was examined a couple of decades later by Arthur H. Kopp who had been appointed in 1932 as the first chemist at the Metropolitan Museum of Art, New York, a position he held just six years before he was tragically killed there in a laboratory fire. According to Nora Scott, who had joined the staff at the Metropolitan Museum of Art in Kopp's day and eventually became head of the Egyptian department, Kopp had examined the Senebtysy diadem microscopically and noted: 'plain evidence that this wire had been cut from sheet and then drawn – square edges are seen here and there, and even shear marks at right angles to the wire axis, while longitudinal streaks plainly show evidence of drawing' (quoted by Aldred 1971, 86–7). What he describes sounds very much like strip-drawn wire where the starting point was a near-square-section strip. My own observations of the wire of the diadem are that it certainly appears to have traces of seam lines that vary from straight along the wire axis to spiralling at a slight angle. Another argument that the Senebtysy diadem is of strip drawn wire is the remarkably long, continuous lengths of wire used. Strip-twist wire is not easy to make if the initial strip is much more than a dozen or so centimetres in length; with strip drawing the lengths can be far greater. We can also note that

Figure 4.13. *Gold wire diadem from the tomb of Senebtysy at Lisht, late 12th to early 13th Dynasty. Metropolitan Museum of Art, Acc. no. 07.227.6, Rogers Fund, 1907.*

the binding on the Khasekhemwy jar (British Museum EA 25567) were formed from two lengths of wire, each getting on for 40 cm long.

There seems little doubt that the wires discussed above, characterized by one or more seams going near enough straight along the length of the wire, sometimes spiralling slightly, represent a technique distinct from strip-twist wires. That this was some form of strip drawing, as first postulated by Williams and Heins and a characteristic of earlier periods, being gradually superseded by strip twist wire after about 2000 BC. Williams and Heins also identified the wires on the 19th–20th Dynasty gold diadem said to be from Saqqara (now Brooklyn Museum 37.702E) as being of strip drawn wire and their photograph shows wires very similar to those just discussed (Williams 1924, pl. iv, d). If correct, this appears to be a late survival of the technique.

Whether or not strip-drawn wire was initially an Egyptian innovation awaits study of gold jewellery from neighbouring lands. Unfortunately, Western Asiatic gold-working techniques have received less interest than Egyptian over the last century. A starting point would be to study more of the wire in the Sumerian jewellery from the Royal tombs at Ur in what is now Iraq, excavated in the 1920s and 30s and now divided between the Iraq Museum, Baghdad, the British Museum and University of Pennsylvania Museum in Philadelphia. Kim Benzel has recently written on the materials and technologies of some of the Ur gold jewellery but although she describes the strip-twist wire-making technique, she does not seem to have unequivocally identified it in the objects she examined (Benzel 2013, 2016). My own examination of several Ur gold items have revealed mostly hammered and burnished wires and simple cut strips, but also some circular section wires that observation without strong magnification suggests might be strip drawn, such as a gold chain with lapis lazuli beads now in the British Museum (ME120585). Further research on early Western Asiatic gold wires is overdue. The apparent lack (so far) of strip-drawn wires at Ur, but its use at Troy raises questions regarding chronology and connections.

Engraving

A hand-worked design on gold, an inscription on a ring bezel for example, can be produced in one of two ways. The gold surface can be deformed or 'chased' with a small punch tapped with a hammer, or be partly removed with a sharper tool, which cuts a groove. In the latter process, termed engraving, the tool can be pushed with hand-pressure alone, or tapped with a hammer. In his study of traditional metal-working in Iran half a century ago, Hans Wulff described both hand pressure and tapping being used by a metal-worker engraving signets (Wulff 1966, 38, fig. 47).

It is usually considered that engraving was impractical with copper alloy tools; they were too soft (in the case of copper) or too brittle (in the case of cold-worked tin bronzes), and so engraving only came into use in the wake of iron. There is engraving, presumably with iron tools, on some Mycenaean gold contemporary with the Egyptian New Kingdom, but engraving does not appear to have been employed on gold jewellery in most of the ancient Mediterranean world until the 1st millennium BC (Ogden 1998). The engraved depressions on the Mycenaean rings are fairly shallow, U-shaped grooves with striations along their length caused by slight imperfections on the cutting edge of the tool. Similar tool marks can be seen in later classical jewellery, such as some Hellenistic and Roman gold rings, although even into post-Roman times such designs were still often chased rather than engraved.

In Egypt, there is a surprise. The designs on some early Egyptian gold objects appear to be engraved with sharp, angular tools. The Middle Kingdom scarab base of Ameny in Figures 4.14 and 4.15, found at Lisht in 1913–14, is an example (Metropolitan Museum of Art 15.3.135b). This clearly has sharp, rather angular cut depressions. Another provenanced example is a gold and amethyst scarab ring of Senusret III excavated by de Morgan at Dahshur in 1894–95 (Metropolitan Museum of Art 26.76.756; Figs. 4.16 and 4.17). The base plate here has cleaner, more parallel sided cuts, but the striations left along the bases of the depressions left by a sharp engraving tool and the abrupt ends of the channels are clearly visible. Somewhat rougher engraving can be seen on the bases of some First Intermediate Period gold button seals, but I have not seen it yet on New Kingdom or later Egyptian goldwork. It is just possible that the designs on the button seals were deeply scratched using a flint tool, but the sharpness and form of the tool marks on the Middle Kingdom gold scarab bases were undoubtedly produced with hard metal tools.

If sharp engraving like this could be produced with copper alloy tools, then we would expect to find similar engraving used widely in the ancient world, which we don't; if it required metal tools other than of copper alloys, what might these have been? One possibility is that some tools of iron, probably meteoric iron, were available in Egyptian royal workshops. Meteoric iron can and has been used for serviceable blades in many parts of the world. There are instances of iron from early Egypt, mostly probably meteoric (Lucas & Harris 1962, 235–9; Rehren et al. 2013). Another

Figure 4.14. *Gold base from a scarab ring with the name of Ameny from Lisht, Middle Kingdom. Metropolitan Museum of Art, Acc. no. 15.3.135b, Rogers Fund, 1915.*

Figure 4.15. *Detail of the ring in Figure 4.14.*

possibility is gold mixed with a significant amount of copper, the result being an alloy that can be as hard as mild steel (around H_v 140). Such alloys were certainly known in Egypt, as we will see in the next section, but I am not aware of any tools made in this material surviving from there. However, small gold-copper alloy tools were discovered in the Royal Tombs at Ur, Iraq, thus of late 3rd millennium BC date (la Niece 1995), and similar gold-copper alloys were used for chisels and other implements in Pre-Columbian South America (Scott & Seeley 1983).

I have not seen engraving as on the Middle Kingdom rings in later periods in Egypt. For example, the inscription on the gold back plate under the scarab in the 17th Dynasty ring in Figure 4.6 was produced in the more conventional ancient chasing technique, although the removal of accretions from the depressions in recent times with a sharp point has left a plethora of disfiguring scratches (Fig. 4.18).

Gold cladding

Gold-copper alloys have an attractive salmon-pink to reddish hue, which might explain their use for some New Kingdom signet rings of so-called stirrup type (Lucas & Harris 1962, 229; Ogden 2000, 164). However, there were other advantages in the use of such alloys – they are far easier to cast than more conventional gold alloys. Casting is the production of a metal object by the pouring molten metal into a mould, a process rarely used for gold jewellery in ancient Egypt or elsewhere in the ancient Old World because the usual range of relatively high purity, yellow gold alloys are not easy to cast. Unfortunately, many cataloguers wrongly assume that any sturdy gold object was cast. Compared with the yellow gold alloys, the gold-copper ones have a lower melting temperature, flow better in the mould and are less prone to porosity. For example, while a typical gold alloy used in pre-Late Period Egypt will have a melting temperature between about 1020 and 1040 °C, the typical gold-silver-copper alloys used for some of the stirrup rings will melt around 900 °C. Thus, we find cast jewellery in reddish gold-copper alloys widely spread, from the Chalcolithic Balkans to South America (Personal observations and Scott 2012 passim).

The reddish gold stirrup rings of the New Kingdom in Figure 4.19 are cast in one piece. Indeed, the hardness and brittleness of such alloys would make hand working almost impossible. The pale greyish coloured gold-silver alloy rings of this type ('electrum') were also typically cast, but the higher purity yellow gold Egyptian gold stirrup rings were seemingly typically produced by hand working the hoop and bezel separately and then soldering these together.

Figure 4.16. *Gold base on a gold and amethyst scarab ring of Senusret III from Dahshur, Middle Kingdom. Metropolitan Museum of Art, Acc. no. 26.76.756, Edward S. Harkness Gift, 1926.*

Figure 4.17. *Detail of the engraving on the ring in Figure 4.16.*

Figure 4.18. *Detail of the base plate on the ring in Figure 4.6 showing chased inscription and recent scratches.*

Figure 4.19. *Two of the pendants from a New Kingdom Egyptian collar found in tomb 93 at Enkomi, Cyprus, British Museum, Acc. no. 1897,0401.535.*

Higher purity gold stirrup rings that appear to have been cast in one piece thus deserve a second look – the fakes are often made this way. One example was sold at auction by Christies, New York, in December 2003[3] for a record price for an ancient ring. The previous owner had purchased it in a London auction earlier that year when it had passed almost unnoted among the collection of antiquities and other objects formerly owned by the late Gavin Todhunter. Todhunter is said to have begun collecting intaglios and other works of art in the 1940s and continued to do so until the 1970s. It is not known when the present ring came into his hands, or where he obtained it, and so, under the policy of the publisher, images of it cannot be presented.

The unknown origin of this ring, its apparent one-piece cast construction and seeming high purity raised concerns about its authenticity when I first saw it. Then there was an accident with a fortuitous outcome. The purchaser at the London auction took the ring to the Assay Office of the Worshipful Company of Goldsmiths in London to be analysed. They started to make a minute scraping on the underside of the bezel, but a small area of the surface became detached revealing that the ring was actually of a reddish copper-gold alloy with a thin, purer gold cladding. The exterior was about 92.4% gold with 4.2% silver and 3.3% copper, the interior 68.4% gold with 3.7% silver and 20.5% copper. This interior composition is as expected for a New Kingdom red gold stirrup ring and thus extremely reassuring regarding its authenticity. The cladding of a cast red-gold ring to make it look like purer gold does suggest that an appearance of purity was a greater consideration than the aesthetic appeal of a pink colouration, and it raises questions about the construction of other one-piece Egyptian stirrup rings of yellow gold. Stripping off a bit of the surface of them is obviously out of the question and X-rays may not reveal anything, but a simple specific gravity test might well be informative.

New Kingdom Egyptian jewellers seem to have been adept at plating high purity gold over lower purity alloys. An example previously published by me was an early 18th Dynasty Egyptian ear- or hair-ring of penannular, tubular form (Ogden 1982, 80, fig. 4.79). This was formed in two halves from a sheet of a gold-silver 'electrum' just 0.12 mm thick over which was bonded a layer of only slightly purer gold averaging about 0.025 mm thick. A minimal saving in material seemingly justified the extra work. The bonding together of the gold and electrum to make the sheet from which the hair-ring was constructed was not a complex procedure, but it is unclear how gold sheet could be applied satisfactorily over the varied topography of a cast stirrup ring. There seems to be too abrupt a change from core to surface to be explained by some deliberate enrichment technique such as dissolving out the copper from the surface using an acidic substance and then burnishing the resulting higher purity surface. Versions of this surface enrichment process were widely used in the past in both the New and Old Worlds. The hardness of the gold-copper alloy core would seemingly rule out working the bezel design with punches after the outer gold surface had been applied.

Further examination of the New Kingdom Egyptian gold stirrup rings as well as other gold objects from antiquity would be useful to determine the various approaches that were used to give a pure gold appearance to ornaments of alloyed gold or base metals, and to ponder what this can tell us about ancient economic and aesthetic values. Clearly destructive testing is inadvisable, but there are many fragmentary objects which can be studied. Indeed, with gold as with other categories of object, broken fragments often provide a wealth of examination opportunities for the researcher.

Enamel

Enamel is glass. Not glass that is cut and set into jewellery, but which has been ground up finely, placed in a hollow, cavity or 'cell' in the metalwork and then heated until it melts and fuses in place. The Egyptians were highly conversant with glass manufacture at least from the early New Kingdom onwards and were extremely fond of polychrome inlaid gold, so it is necessary to ask why ancient Egyptian enamel is so elusive (Ogden 2009). Alfred Lucas, for example, noted various earlier misidentifications of glass and stone inlays in Egyptian jewellery as enamel, stating that 'enamel, however, was not used in ancient Egypt' (Lucas & Harris 1962, 116–17). Cyril Aldred suggested that the red inlays on a vulture pectoral among Tutankhamun's jewellery might be enamelled, but Emily Teeter's microscopic examination revealed that the enamel-like appearance of the inlays was due to the presence of 'a soft material which has a distinctly resinous odour' (Aldred 1971, 221; Teeter 1981).

In some cases, what appears to be enamel in Egyptian jewellery is crushed frit mixed with a binder, what Marc Rosenberg erroneously saw as a precursor to true enamel (Rosenberg 1921, 12–14). One of the examples cited by Rosenberg was the Egyptian gold broad collar found in tomb 93 at Enkomi, Cyprus, along with other jewellery including a ring of Akhenaten (Marshall 1911, 36–7, no. 581). My examination of this object confirmed that several of the cells in the lotus terminals and other components do contain a crushed blue frit, apparently coloured by cobalt, mixed with an organic binder of some sort. Two pendants from this group are shown in Figure 4.21; the blue material is clearly seen in the lower recess on the right-hand pendant. However, this material is not the actual inlay, but a typical backing material for inlays. In several of the components of this collar, this material retains the impression of the missing inlays, in some the original inlays of greyish-blue glass are still in place over the backing.

While there remains a real possibility for some enamel among New Kingdom Egyptian goldwork, the only Egyptian gold objects of dynastic date which I have seen so far, which I believe to have a good chance of being true enamel, are two objects found at Tanis, now in the Cairo Museum. One is a pectoral from the tomb of Wendjebaendjed, an important minister in the Third Intermediate Period (Montet 1951, 82–3, no 773, pl. 54; Paris 1987, no. 79; Ogden 1990). A detail of this is shown in Figure 4.20. The whitish inlays appear to be conventional cut inlays, but the bluish-green glass appears to be fused in place, or at least applied in a semi-pasty state. It now shows some crazing. Certainly, it follows the contours, particularly the irregularities of the corners, of the cells very precisely and, in places, seems to overlap the cells. The long section horizontally across the centre in Figure 4.20 shows this most clearly. Other pectorals from Tanis may contain similar inlays and one, that in Figure 4.21, also from Wendjebauendjed's tomb but which I haven't seen in person, was described by Montet as containing enamel (Montet 1951, 76, pl.49).

Another possible example, also from Wendjebaendjed's tomb is a gold bowl (Montet 1951, 82–3, cat 773, pl. 54; Paris 1987, no. 79). Here the decoration in the centre is an inset motif in the form of a complex rosette (Fig. 4.22). At close range, but sadly, so far not in the laboratory, at least some of the inlays appear to me to be enamel and the form of this rosette, the design and its colour palette are reminiscent of six

Figure 4.20. *Detail of a gold and glass (perhaps enamel) pectoral from the tomb of Wendjebaendjed at Tanis, Third Intermediate Period, Acc. no. JE 87740, Cairo Museum.*

enamelled gold rings found in a hoard of jewellery in a Mycenaean tomb at Kouklia, Cyprus (Catling 1968). These date to about 1200–1150 BC. Herbert Maryon described the construction of these rings in some detail and there is no doubt that they are enamelled in a version of the cloisonné technique (Maryon 1971, 170–1). The Cyprus rings are a century or so earlier

Figure 4.21. *Detail of a gold and glass (perhaps enamel) pectoral from the tomb of Wendjebaendjed at Tanis, Third Intermediate Period, Acc. no. JE 87740, Cairo Museum.*

than the time of Wendjebaendjed, but a reuse of the bowl, or the mounting of an imported older motif on it, are not impossible. His tomb contained numerous reused precious objects including objects with the names of Rameses II. The bowl bears an inscription noting that it had been presented to Wendjebaendjed by Psousennes, but its position on the rim would not exclude the possibility that it had been added then.

The apparent lack of ancient Egyptian enamelled gold other than a handful of possible examples requires an explanation. One reason was presented by glass expert Edward Dillon more than a century ago in an article in the *Burlington Magazine*, where he says 'the reason the Egyptians had no true enamels is simply this: they were unacquainted with the application of lead to form a readily fusible glass.' (Dillon 1907). Lead oxide in glass and enamel has several useful functions. It lowers the melting temperature, makes the molten glass really fluid so it flows and bonds well, and it makes the coefficient of expansion of the glass closer to that of the surrounding metal – if the glass and metal expand and contract at different rates during firing and cooling the enamel is liable to crack and flake off. In general, there is little evidence for lead in glass prior to Roman times. There are some exceptions, primarily with yellow glass, and Christine Lilyquist and Robert Brill have shown the use of yellow glass containing lead in Egypt from at least as early as the time of Tuthmosis III (Lilyquist & Brill 1993). However, yellow glass is hardly well suited to being set into yellow gold.

Opaque orangey-red glasses owe their brilliance to high lead, but these are not known in Egypt, or seemingly elsewhere in the Mediterranean world, until the

Figure 4.22. *Detail of the enamelled disk in the centre of a gold bowl from the tomb of Wendjebaendjed at Tanis, Third Intermediate Period, Acc. no. JE 87740, Cairo Museum.*

Third Intermediate Period (Bimson 1987). This glass owes its red colour to copper and cannot be used as a true enamel because if it is ground and remelted it turns green. The only way it can be inlaid in metal is to heat it until it is just soft when it can be pressed into place. I am not aware of any use of this technique on gold in Egypt, although some use in copper alloys in Late Period Egypt seems possible. Ancient copper alloys could not be enamelled with more conventional enamels, because the alloys had too low a melting temperature. Incidentally, it was the lack of any red inlays in the Wendjebaendjed pectoral in Figure 4.20 that first drew my attention to it and suggested that something might be different about its materials. Red inlays would be expected in a conventional inlaid Egyptian pectoral.

Lack of lead is not the whole answer as to why we do not find Egyptian enamelled gold, because the fine enamels on gold, which we find in other parts of the Old World from the 1st millennium BC and into Middle Byzantine times, generally lack significant lead. Important was heat. Enamel must melt and flow at a temperature lower than the melting temperature of the gold itself. For a good bond, enamel needs to be heated to slightly above its melting point, to its 'maturing point', in order to spread evenly into the exact shape of the setting. Paul Nicholson and Julian Henderson have most recently said that 'the softening and working temperatures for an Egyptian soda-lime-silicate glass of the 2nd millennium BC were between c 1000 °C and 1100 °C' (Nicholson & Henderson 2000, 218). Some of the poorer glasses might have melted around 870 °C, even less, but these would not produce good glassy enamel.

In practice a temperature getting up to 1000–1100 °C would be necessary for a good enamel on gold using the then available glass. Ancient Egyptian gold purities can range from under 50% up to more than 90%, but around 70–85% seems typical of most jewellery of the Middle and New Kingdoms (Ogden 2000). The typical gold alloys used by the ancient Egyptians would start to melt between about 1020 °C and 1040 °C, so in practice Egyptian gold jewellery objects could not be enamelled without the very real risk, in many cases likelihood, that the gold components would start to melt or come apart. As the Mycenaean and possible Tanis examples show, a few accomplished jewellers were able to choose their alloys and control their furnaces, but the wider absence of enamelled gold is explainable. It is probably not coincidence that fine polychrome enamels in gold only came into common use in the ancient world about the time that there seemed to be systematic refining for gold alloys. The refining of gold permitted greater control over the gold alloys used in jewellery, rendering their behaviour less unpredictable. The ability of the Medieval goldsmiths to enamel quite debased gold alloys without using lead-containing enamel has to be admired and may point to a significant improvement on the ability to control the heat source (Ogden 2020).

In Eastern Mediterranean world and up into the Black Sea, enamelled gold jewellery becomes commoner after about the 5th century BC, particularly in Classical Greek and Hellenistic Greek jewellery. The occasional enamelled Egyptian ornaments in gold we encounter, such as *wedjat*-eyes, typically belong in the Ptolemaic or early Roman Periods (Ogden 1990, vol 1, 178, 190, 210–11). Arielle Kozloff described a group of bird and animal figures in sheet gold with cloisonné enamel decoration: a falcon in the Walters Art Gallery, an ibis and lion in Boston, a sphinx in Athens and a lion in Cairo

(Kozloff 1976). I would agree with Kozloff, and with Lilyquist (Lilyquist 1993, 37 note 25), that the objects cannot be any earlier than the Ptolemaic Period, but I am not convinced that all are ancient. I have not had the opportunity to examine any of them in detail, but William Young's analysis of the Boston lion, as published by Kozloff, is not reassuring. The lion's body is apparently of pure gold, with neither silver nor copper detected. This would be highly unusual in antiquity, though it is quite common with some older Egyptian fakes. Also, the inlay material had lead as a major constituent; something which would be highly unexpected.

We also find enamelled Egyptian motifs in Phoenician goldwork, some perhaps predating the mid-1st millennium BC and there is the magnificent Meroitic enamelled gold jewellery from what is now Sudan. In the Meroitic work, which dates from the 3rd to 1th century BC, we find a whole range of enamel types (Markowitz & Doxey 2014, 148–51; Lacovara & Markowitz 2019, passim; Ogden 1989). The origin and relationships of this Meroitic enamel work is still uncertain, although the earlier goldwork from Nubia might owe as much to Phoenician and South Arabian as to Egyptian influence. One can imagine Phoenician trade routes from Southern Arabia passing across the Sudan and up to the Phoenician centres on the North African Coast, avoiding the Persian Empire, which then included Egypt itself.

The above has presented a look at just four aspects of ancient Egyptian jewellery technology that raise questions and prompt further study. Such study will tell us more about Egyptian goldsmithing traditions and, providing such research encompasses neighbouring lands, reveal much about cultural connections. It is also important to reiterate Petrie's comment from almost a century ago – that a description of methods of manufacture of jewellery should be 'a necessary part of any catalogue'.

Notes

1. The 1932 2nd Edition has only minor updates.
2. Oddy 2004 summarizes, and gives a bibliography, of his work on the manufacture of wire over the previous decades.
3. Christies, New York, 11 December 2003, sale 1313, Ancient Jewelry, Auction 11, lot 336.

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This book aims to provide a new level of synthesis in the study of gold jewellery made in Egypt between 3500 BC and 1000 BC, integrating the distinct approaches of archaeology, materials science and Egyptology. Following accessible introductions to the art and use of gold in Ancient Egypt, and to current advances in technical analyses, the volume presents detailed results on the manufacturing technology and elemental composition of some 136 objects in the collections of six European museums, with discussion of the findings in historical and cultural contexts. The questions generated by the jewellery buried with a woman and a child at Qurna (Thebes) led to investigation of assemblages and individual artefacts from later and earlier periods in varied social contexts, from the rural environment of Qau and Badari, to sites connected with urban or royal centres, such as Riqqa, Haraga and Lahun. A final discussion of the Qurna group provides an agenda for future research.

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