BIBLIOGRAPHY TELL EL-DAB'A

M. Bietak, 1984, "Eine Palastanlage aus der Zeit des späten Mittleren Reichs und andere Forschungsergebnisse aus dem östlichen Nildelta (Tell el-Dab'a 1979-1984)", *Anzeiger der phil.-hist. Klasse der Österreichischen Akademie der Wissenschaften*, 121, p. 313-349.

M. Bietak, 1989, "The Middle Bronze Age of the Levant- A New Approach to Relative and Absolute Chronology", in, P. Åström, (ed.), *High, middle or low? Acts of an* International Colloquium on Absolute Chronology held at the University of Gothenburg, 20th-22nd August 1987, Part 3, SIMA Pocketbooks 80, Gothenburg, 1989, p. 78-120.

M. Bietak, 1991a, "Egypt and Canaan in the Middle Bronze Age", *BASOR*, 281, p. 27-72.

M. Bietak, 1991b, "Der Friedhof in einem Palastgarten aus der Zeit des späten mittleren Reiches und andere Forschungsergebnisse aus dem östlichen Nildelta (Tell el-Dab'a 1984-1987)", *Egypt & Levant,* 2, p. 47-75.

M. Bietak, 1991c, *Tell el-Dab'a V. Ein Friedhofsbezirk der Mittleren Bronzezeitkultur mit Totentempel und Siedlungsschichten,* Teil 1. UZK 8, Vienna.

M. Bietak, 1993/1994, "Der Übergang der Frühen zur Mittleren Bronzezeitkultur im Vorderen Orient anhand von Wandbildern in Gräbern des ägyptischen Mittleren Reiches", *Mitteilungen der Anthropologischen Gesellschaft in Wien* 123/124, p. 391-399.

M. Bietak, 1996, *Avaris. The capital of the Hyksos. Recent Excavations at Tell el-Dab'a*, London.

M. Bietak & E. Strouhal, 1974, "Die Todesumstände des Pharaos Seqenenre (17. Dynastie)", *Annalen des Naturhistorischen Museums*, Vienna, p. 29-58.

L. Borchardt, 1913, *Das Grabdenkmal des Königs Sahure II*, Leipzig.

M. Chéhab,1937, "Un trésor d'orfèvrerie syro-égyptien", *BMB,* I, I, p. 7-21.

I. Forstner-Müller, 2008, *Tell el-Dab'a XVI. Die Gräber des Areals A/II von Tell el-Dab'a*, UZK28, Vienna.

I. Hein, & M. Bietak, (eds.), 1994, *Pharaonen und Fremde. Dynastien im Dunkeln.* 194. Sonderausstellung des Historischen Museums der Stadt Wien in Zusammenarbeit mit dem Ägyptologischen Institut der Universität Wien und dem Österreichischen Archäologischen Institut Kairo, Rathaus Wien, Volkshalle, 8. Sept.-23 Oktober 1994, Vienna.

K. Kopetzky, 1993, *Datierung der Gräber der Grabungsfläche F/I von Tell el-Dab'a anhand der Keramik*, unpublished M. A. thesis, Vienna.

K. Kopetzky, 2004, "The Royal Tombs I-III of Byblos. A New Chronological Approach", Lecture held during the 4th ICAANE in Berlin 2004 in the workshop "*stratigraphie comparée*".

K. Kopetzky, 2010, *Tell el-Dab'a XX. Die Chronologie der Siedlingskeramik der Zweiten Zwischenzeit aus Tell el-Dab'a,* UZK 32, Vienna.

J. de Morgan, 1895, *Fouilles à Dahchour,* mars-juin, 1894, Vienne.

P. E. Newberry, 1893, *Beni Hassan* I, London.

G. Philip, 1989, *Metal Weapons of the Early and Middle Bronze Ages in Syria-Palestine,* BAR International Series 526, vol. ii.

G. Philip, 2006, *Tell el-Dab'a XV. Metalwork and Metalworking Evidence of the Late Middle Kingdom and the Second Intermediate Period*, UZK26, Vienna.

R. Schiestl, 2002, "Some links between a Late Middle Kingdom Cemetery at Tell el-Dab'a and Syria-Palestine: The Necropolis of F/I, Strata d/2 and d/1 (=H and G/4)", in: M. Bietak, (ed.), *The Middle Bronze Age in the Levant.* Proceedings of an International Conference on MB IIA Ceramic Material, Vienna, 24th-26th of January 2001, CChEM 3, Vienna, p. 329-352.

R. Schiestl, 2009, *Tell el-Dab'a XVIII. Die Palastnekropole von Tell el-Dab'a. Die Gräber des Areals F/I der Straten d/2 und d/1.* UZK 30, Vienna.

Archaeology & History in the Lebanon Issue Thirty Four-Thirty Five: Winter/Spring 2011/12. Pp. 53-59.

GOLD AND IRON FINGER RING FROM A MIDDLE BRONZE AGE GRAVE IN SIDON

DAFYDD GRIFFITHS
JOHN MERKEL

1 A gold and iron finger ring from a Middle Bronze Age grave of a female (burial 102) on College site in Sidon. This view is from an elevated angle near to the axis of the ring. It shows the plano-convex section of the iron band, now incomplete and apparently completely corroded. This figure also shows the gold band that forms the inner lining of the ring and the fine row of granulation along the upper edge of the ring.

A gold and iron finger ring was found in a Middle Bronze Age grave of a female (burial 102) on the College site in Sidon (see C. Doumet-Serhal & K. Kopetzky, p. 39) in the same grave in which a gold cylindrical pendant was found, (see p. 40 and 60)

Description and discussion of the manufacture of the ring

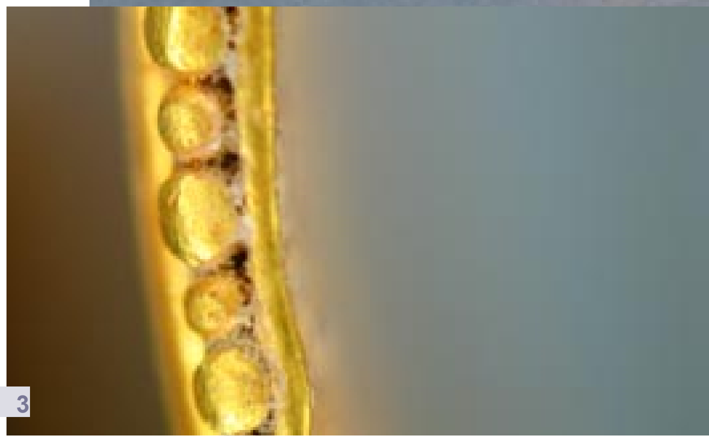
The finger ring comprises a broad gold band with two narrow bands of granulation (tiny gold spheres) that border both edges of the ring. Between the two bands of granulation is a broad band of iron with a plano-convex section. Although the iron band is now incomplete and appears to be entirely corroded, it is likely that in use it would have been a complete metallic iron band and have been silver grey in colour, standing out in handsome contrast against the peripheral bands of gold granulation.

In the Sidon ring it seems as though iron is being treated as a "jewel" and the gold is used as a setting, albeit a very elegant setting, for the iron. Based on the number of known excavated gold alloy objects from the period, gold appears to have been much more common than iron. It is of course the case that the marked difference in susceptibility to corrosion between gold and iron will have distorted the picture by differential survival. Nevertheless, it seems likely that iron (whether meteoric or smelted) was very rare in this period. This view is further supported by records of iron being included in tribute to Egyptian pharaohs in the time of Amenhotep III and Amenhotep IV (see below).

The ring measures approximately 0. 7 cm between what would have been its proximal and distal edges when it was worn. (In other words, the height between the upper and lower edges when the ring is resting on a flat surface is about 0. 7 cm.) The ring has an internal diameter of approximately 1. 6 cm and a maximum external diameter of approximately 2. 2 cm (figs. 1 and 2).

The broad gold band appears to have been made by bending a rectangular piece of gold sheet about 0. 7 cm by 5. 0 cm into a circle to make a ring. This sheet was approximately 0. 2 - 0. 3 mm thick (fig. 3). A single soldered join line runs perpendicular to the edges of the sheet holding the ends of the sheet together to form a ring (fig. 4). The similar colour of the join suggests that the alloy of the solder is not very dissimilar in composition to the alloy of the gold band.

2 A gold and iron finger ring from a Middle Bronze Age grave of a female (burial 102) on College site in Sidon. This view is from the side, nearly at right angles to the axis of the ring. The plano-convex shape of the iron band is clearly seen, albeit the band is now incomplete and apparently completely corroded. This figure also shows the gold band that forms the inner lining of the ring and the two fine rows of granulation, one bordering the upper edge of the main gold band and the other bordering the lower edge.



3 This is a view looking parallel to the axis of the ring and looking vertically downwards with the ring resting on a horizontal surface. The main gold sheet comprising the inner lining of the ring is seen across the upper part of the image. A row of granules is seen in the centre. Across the lower part of the image (slightly out of focus because it is further away from the camera) is the outer edge of the wire that runs around the periphery of the main gold band beneath the row of granules. The field of view is approximately 3. 5 mm from side to side.

The main gold band of the finger ring has two additional thin bands of gold attached to the outside of the ring about 0. 5 mm in from each edge. These bands appear to have been made of wire approximately 0. 6-0. 7mm in diameter. Scratches on the surface of the wire that might have arisen during use are visible in figures 5 and 6.
In the angle between each of the peripheral bands and the adjacent edge of the main ring is a single row of granulation, a row of small spheres of gold each approximately 0. 4 - 0. 5 mm in diameter (figs. 5 and 6).
The diameter of the granules generally appears slightly less than that of the wires used to make the two peripheral bands. A possible way of making the spherical granules may have been to use some wire slightly thinner than that used to make the peripheral bands, to cut this wire into short sections and to heat the short sections without letting them touch each other. When the wire fragments melted they would form into spheres due to the surface tension of the then liquid alloy [1].

Maryon reports that the techniques and skills of soldering fine spherical granules (granulation) and wires (filigree) of gold and silver to make the finest decoration appear to have been lost at various times in the past. Many attempts were made in the nineteenth century to copy the finest ancient filigree and granulation. Eventually a Mr. Littledale devised a method of fixing the granules or wires in place with small amounts of a mixture of copper carbonate and glue. When heated, the glue turns to carbon which then reduces the copper salt (which may previously decompose to copper oxide) to copper. The copper diffuses into the gold to form a fine film of solder just where needed by reducing the melting point of the alloy into which the copper has diffused [2].

Ogden believes that this type of technique was probably used for much granulation work in ancient times [3]. He notes, however, that in some cases (such as a gold cylinder pendant from Harageh in Egypt now in the Petrie Museum at University College London (UCL6482) a silver-based solder may have been used to fix the granulation [4]. Investigations into the granulation-decorated gold jewellery found in Troy by Schliemann confirm the use of reaction solders for granulation in the Early Bronze Age [5].

4 This figure shows the soldered join line visible on the inside of the main gold band of the finger ring.

In some areas on the Sidon ring, the relatively thin main band of gold looks as though it may have been partly folded over the top of the granules. This might reflect a slight error in the positioning of the soldered wire bands with respect to the edge of the main band, leaving the row of granules slightly beneath the edge of the main band. On the other hand, the apparent slight folding of the main band over part of the granules is only seen in some parts of the periphery and seems more likely to be the result of wear during use (fig. 6). It is clear that the ring was worn for quite some time in life as a good number of the granules show clear signs of wear.

Scratches on the wire under the granules (fig. 5 and fig. 6) may also have arisen during use. In terms of inferring the manufacturing process used in making the ring, it may be noted that the forging of the plano-convex section of the iron band would have required considerable heat during hot working and would have required heavy beating. This could hardly have been conducted with the soft and delicate gold and solder components already in place. Some of the working of the iron might have been done cold but a metallographic section of uncorroded metal would be required to distinguish hot working from cold working. Due to corrosion, it is not possible to determine whether the two ends of the iron band were welded together into a ring.

5 A view looking down on the edge of the ring showing the row of granules that borders the edge of the main band. The wider gold band below the granules is the peripheral wire band against which the granules rest. This wire shows linear scars along its length which may be the result of wear. The narrower upper gold band is the edge of the main gold band that lines the ring. The field of view is 11 mm from side to side.

Heat would also have been required to solder the main part of the gold ring, to fix the peripheral wires and to fix the granulation, but not so much heat as to damage the gold components themselves, nor the iron. (The essence of a solder is that it is an alloy which melts below the melting temperatures of the adjacent alloys). Granulation was done under reducing conditions to allow reduction and minimize oxidation. One possibility for the sequence of manufacture is that the iron ring was made first, then the gold band inserted into the iron ring, and then the gold wires and granulation applied. Whether the soldering of the gold components was done in stages using progressively lower temperatures (and lower melting solders) for each stage or done in a single heating episode is not yet established. Given the presence of a previously formed iron ring, it is possible that all the gold components could have been mounted and soldered together in a single heating episode. The atmosphere for the granulation would have needed to be reducing to minimize oxidation: this would also minimize oxidation of the metallic iron if this was already in place. It seems quite likely that the iron ring was made first as this would allow it to be hot worked and possibly have the ends welded together (at around 700-10000 degrees centigrade) to form a continuous ring. The completed ring of harder iron could then readily be fitted with an inner gold band cut to length and soldered to match the inner circumference of the iron ring.

An alternative possibility for manufacture might be that the gold ring was made first and a slightly open iron ring then beaten closed around the gold ring by cold working. This would be feasible but less elegant as the iron ring would not then be continuous, albeit that any gap could be filled.

There are a number of early instances of iron being used with gold. Gold was used to inlay decoration on iron objects. Clay tablets from the Amarna Period refer, to the presentation by Tusratta, King of Mitanni, of two “hand-rings of iron, overlaid with gold” to Amenhotep III (around 1350 BC) and “ten rings of iron, overlaid with gold” to Amenhotpe IV [6]. Although the above examples attest to the use of gold and iron in rings, they may simply refer to the overlaying of gold foil on baser materials. This was a common technique, the use of which is attested, for example, in the cylindrical gold pendant found in the very same grave as the Sidon gold and iron ring. To the best of the authors’ knowledge, however, the design of the Sidon ring remains

6 This is a view from the side of the ring showing the row of granules that border the edge. The wider gold band below the granules is the peripheral wire band on which they rest: it shows linear scars along its axis which may be the result of wear. The edge of the ring at this point on the periphery shows considerable signs of wear to the upper edge of the main gold band that lines the ring and to the granules. The field of view is approximately 4.8 mm from side to side.

unique.

The origin of iron in early archaeological artefacts

There is much archaeological and archaeometallurgical interest in whether iron used in early periods was obtained by smelting iron ores or obtained from iron meteorites. Analyses of metallic meteorites show that they contain substantial amounts of nickel. Analyses of several hundred iron meteorites by Buchwald showed that none contained less than 5 wt% nickel. Although some contained up to about 35 wt% nickel, the great majority contained 5-15 wt% nickel [7].

Early metallic artefacts are sometimes analysed in an attempt to determine whether they are made of smelted iron or meteoric iron. Interpreting the analytical results is not, however, an entirely simple exercise as, depending on the nature of the ore, nickel can also be present in some smelted iron [8]. Nevertheless, for artefacts in good condition, the nickel content remains a clue as no meteorites contain less than 5 wt% nickel and smelted alloys with more than a few percent nickel are rare [9]. Whether an alloy with more than 5 wt% might be the result of smelting is still not clearly established [10].

6

As an example of analysis of an ancient artefact conducted in an attempt to investigate this question, an iron dagger from the tomb of Tutankhamun (dated to around 1325 BC) was analysed by non-destructive X-ray fluorescence spectroscopy of the surface and was found to contain about 2. 8 wt% nickel. The surface of the dagger blade appeared to be in good condition so it was concluded that the dagger was not made from meteoritic iron [11].

A complication in assessing whether an ancient iron artefact is made of smelted iron or meteoric iron is that the processes of corrosion can alter the proportions of iron and nickel remaining in the artefact. Ogden states that “long buried meteoric iron artefacts can have much, if not most, of the nickel leached from them” [12]. Because of this complication, it is sometimes assumed that very early iron artefacts are probably reworked meteoric iron, even if the nickel content in corroded areas is found to be below 5 wt%.

A relevant example in the present context is the analysis of corroded iron beads found in Predynastic graves at Gerzeh, 70 km south of Cairo and now in the Petrie Museum, University College London [13]. Polished sections through the corrosion products were analysed by electron probe microanalysis using X-ray spectroscopy. These analyses were

reported as finding 51-59 wt% iron, 0-0. 2 wt% nickel and 0. 03-0. 5 wt% copper depending on the location analysed. The other components reported are probably contaminants from soil trapped in the corrosion. It was concluded that while the analytical results did not completely rule out a meteoric origin, the low nickel concentrations did not particularly support the argument previously made in favour of a meteoric origin.

Analytical results

Returning to the present case, the iron band around the Sidon ring now appears to be entirely corroded. A small speck of corrosion from the iron was loose in the sample container. This was subjected to non-destructive energy dispersive X-ray spectroscopy in a scanning electron microscope, primarily with the purpose of investigating its nickel content and the possible origin of the iron. These analyses were non-destructive analyses conducted directly on the fragment, not on a polished section as in the example above. Because of surface irregularities and large differences in porosity between the areas analysed, the results needed to be normalized to facilitate comparison. Out of 18 areas analysed, nickel was detected in only half of them. (If nickel was present in the areas where it was not detected, the level must have been below about 0. 1 wt%). Elements attributable to soil contamination were found in all areas analysed. With normalized results including all elements detected (that is including those that are likely to have originated from soil contamination), the highest level of nickel found was 1. 2 wt%. If the above concentrations were normalized on the basis of iron and nickel alone (in other words excluding the soil contamination elements and assuming the band was originally simply an iron-nickel alloy) and ignoring possible distortion of the ratio by corrosion, the nickel content in the band could have been around 3. 5 wt%. This was the highest proportion of nickel to iron found in the very small flake of corrosion after 18 analyses of different areas: in half the areas analysed no nickel at all was detected. Only if severe depletion of nickel content due to corrosion can be assumed would these analyses be consistent with a possible meteoric origin of the iron on the Sidon gold and iron ring. The possibility of drawing more definitive conclusions must await a better understanding of the corrosion of meteoric iron and changes in nickel concentrations.

Conclusions

As regards the origin of the iron band on the Sidon ring, present understanding would allow the possibility that it was originally meteoric iron if much of the original nickel had been lost during corrosion processes. With the current state of knowledge, however, the conclusion has to be that it is not known whether the iron band on the Sidon ring came from a meteorite or from a smelted ore.

Whatever the origin of the iron, however, it remains the case that the gold and iron finger ring found in the Middle Bronze Age grave at Sidon displays masterful craftsmanship in its manufacture. To the best of the authors' knowledge, the ring is of a design hitherto unparalleled, furthermore a design that prior to corrosion would have had considerable aesthetic appeal.

The Sidon ring may be seen as displaying iron as a "jewel" in a setting of gold. Contrasting the values of today with those suggested by the Middle Bronze Age Sidon ring provides an interesting example of how the relative values accorded to different materials depend heavily on the cultural context, on the technological context and on availability.

To judge by the wear on the granulation, this gold and iron ring was a jewel worn for quite some time during the life of the owner. Whatever its significance to the wearer, it may be inferred that the ring held significance during the wearer's life and not only in death. The significance of this remarkable ring as perceived in the culture in which it was worn is not known at present. Nevertheless, at least a little insight into the culture and society of an elite female in Middle Bronze Age Sidon may be gained by observing that the ring was much worn in life. Furthermore, it was deemed by those who buried the woman that it

NOTES

1 H. Maryon, 1971, p. 53-54.
2 H. Maryon, 1971, p. 9-11.
3 J. Ogden, 2000, p. 165.
4 J. Ogden, 1992, p. 52.
5. H. Born, S. Schlosser, R. Schwab and E. Pernicka, 2009. See also J. Wolters, 1981 and J. Wolters 1983.
6 A. Lucas and J. R. Harris, 1962, p. 240.
7 W. Rostoker and B. Bronson, 1990, p. 201.
8 W. Rostoker and B. Bronson, 1990, p. 41.
9 W. Rostoker and B. Bronson, 1990, p. 201-203.
10 W. Rostoker and B. Bronson 1990, p. 20.
11 F. Helmi and K. Barakat, 1995.
12 J. Ogden, 2000, p. 167.
13 E. S. El Gayar, 1995, p. 11-12.

BIBLIOGRAPHY

H. Born, S. Schlosser, R. Schwab and E. Pernicka, 2009, "Granuliertes Gold aus Troia in Berlin: erste Technologische Untersuchungen eines Anatolischen oder Mesopotamischen Handwerks", (Granulated gold from Troy in Berlin: first technological investigations of an Anatolian or Mesopotamian handicraft), *Restaurierung und Archäologie*, 2, p. 19-30.

E. S. El Gayar, 1995, "Predynastic Iron Beads from Gerzeh, Egypt", IAMS, *Journal of the Institute for Archaeo-metallurgical Studies*, vol. 19, p. 11-12.

A. Lucas, 1962, *Ancient Egyptian Materials and Industries*, 4th edn., Edward Arnold, London.

H. Marion, 1977, *Metalwork and Enamelling*, 5th edn., Chapman and Hall, London.

J. Ogden, 1992, *Ancient Jewellery*, British Museum Press, London.

J. Ogden, 2000, "Chapter 4: Metals", in P. T. Nicholson and I. Shaw (eds.), *Ancient Egyptian Materials and Technology*, Cambridge University Press, Cambridge, p. 148-176.

W. Rostoker and B. Bronson, 1990, *Pre-industrial Iron: its Technology and Ethnology*, Archaeomaterials monograph n° 1, Philadelphia.

J. Wolters, 1981, "The ancient craft of granulation", *Gold bulletin*, 14, n° 3, p. 119-129.

A CYLINDRICAL GOLD PENDANT FROM A MIDDLE BRONZE AGE GRAVE IN SIDON

ARCHAEOLOGY & HISTORY IN THE LEBANON ISSUE THIRTY FOUR-THIRTY FIVE: WINTER/SPRING 2011/12. PP. 60-67.

DAFYDD GRIFFITHS

Description and discussion

A cylindrical rod-shaped gold pendant was found in the in the Middle Bronze Age grave of a female (burial 102) on College site. This grave also contained a gold and iron ring (see C. Doumet-Serhal & K. Kopetzky, p. 39 and D. Griffiths, p. 53).

1

1 Pendant from burial 102 made of gold alloy foil wrapped around a copper core. The copper core has corroded badly and shows as green corrosion products beneath the decorated gold foil covering which has been split open by the corrosion. The upper end of the pendant is on the right hand side of the photograph. It may be seen that the upper end cap has split open, showing that it encapsulates the upper part of the decorated gold foil wrapping.

The pendant is about 4.7 cm long and about 0. 6 cm in diameter. It is formed of decorated gold foil wrapped around a copper (or possibly bronze) core (fig. 1 and 2). As can be seen in these figures, the green copper corrosion products occupy more volume than the original copper core and the corrosion has split the decorated foil that encased it. Each end of the pendant bears a plain gold foil cap. One of the caps has part of the end missing (fig. 3). This is interpreted as the upper end of the pendant where a fixing (now absent) might have allowed the pendant to be suspended. Beneath where the gold is missing from the top part of the upper cap, there is what appears to be a small, central piece of green corroded metal, possibly the stump of a copper strip that might once have formed a loop for suspension. The narrow central piece of metal below the level of the top of the

2

2 A view of the pendant from the other side. Again the top of the pendant is on the right side of the photograph.

upper cap is surrounded by an off-white filler around which the upper gold cap was fitted. The filler is needed to fill the space between the thin central stump of metal and the gold foil cap. Given the extent of the corrosion that can be seen on the core, it is quite likely that the thin

3 An end view of the gold cap at the upper end of the pendant. The cap is about 0. 6 cm in diameter. Beneath the top end of the cap is a thin copper strip in the centre surrounded by an off-white filler

4 A side view of the gold cap at the upper end of the pendant.

strip that could have formed a loop for suspension may have been lost through corrosion.

3

In figures 1 and 2, the top of the pendant is on the right-hand side of the photographs. It can be seen that one side of the upper cap has split (fig. 1) and that on the other side of the upper cap (fig. 2) part of the lower margin has been torn upwards.

Although the interpretation as a pendant that has lost its supporting loop is very likely, it should be noted that Newman states that some cylindrical pieces of stone from Middle Kingdom female burials in Egypt have metal end caps but no sign of having been worn as pendants, appearing rather to be amulets [1]. The Sidon pendant is very similar in appearance to a pendant found at Tell el-Dab'a in the Nile delta (see p. 40).

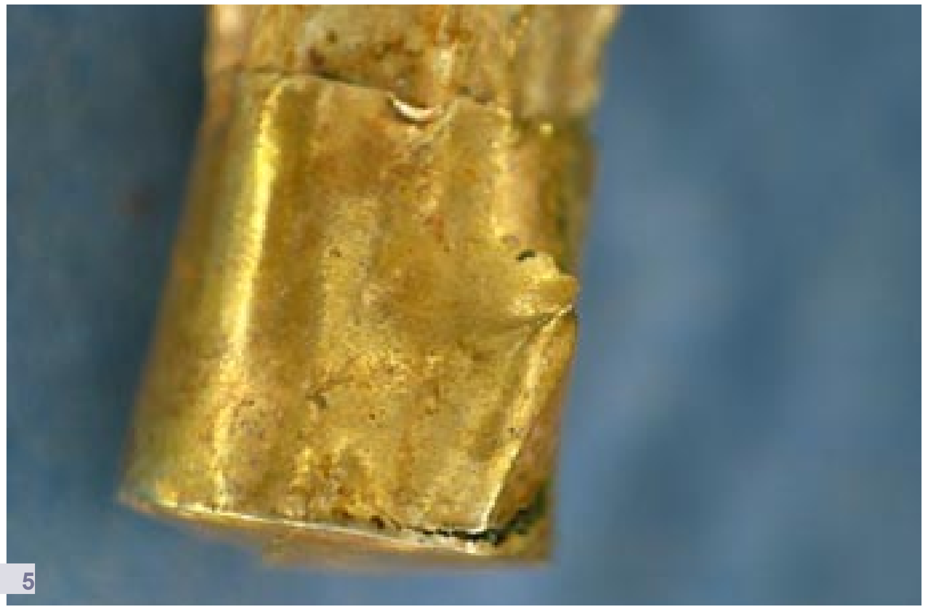
4

Figures 2 and 4 show the upper cap from the side. The tear in the end cap shows that it encases and covers the upper end of the decorated foil.

5 The gold cap at the bottom end of the pendant showing a tear near the join between the edge of the end disc and the cylinder forming the sides of the cap.

Moving now to the lower end cap, the bottom end of this cap appears to have a very slightly greater diameter than its upper rim (see left-hand end of fig. 1 and 2). The lower end cap thus appears to form the base of a truncated gradually tapering cone rather that the base of a cylinder. This form of end cap widening slightly towards the end is also seen on a cylindrical pendant from Haregeh in Egypt, now kept in the Petrie Museum at University College London (UC 6482) [2].

Figures 5 and 6 show the lower end cap. As can be seen from the green corrosion under the tear in the lower cap (fig. 2, 5 and 6), the copper rod extends to the end of the lower cap and there is no need for filler. This difference in the upper and lower end of the core, with the upper end being thinned into a narrow strip, gives further support to the idea that the object was a pendant. The appearance of the join between the circular end piece of the lower cap and the side of the cap might suggest that the circular end of the cap was soldered onto the foil cylinder that constitutes the side of the cap [3] (see fig. 5 and 6). The appearance of the corresponding join on the upper end cap (fig. 3 and 4) also suggests that it also may have been soldered. The sides of the caps were probably made from strips of foil bent into cylinders. The join between the ends of the strips running down the sides of the caps were probably also soldered although the evidence for this is less clear. There is a more or less linear split along the side of the upper

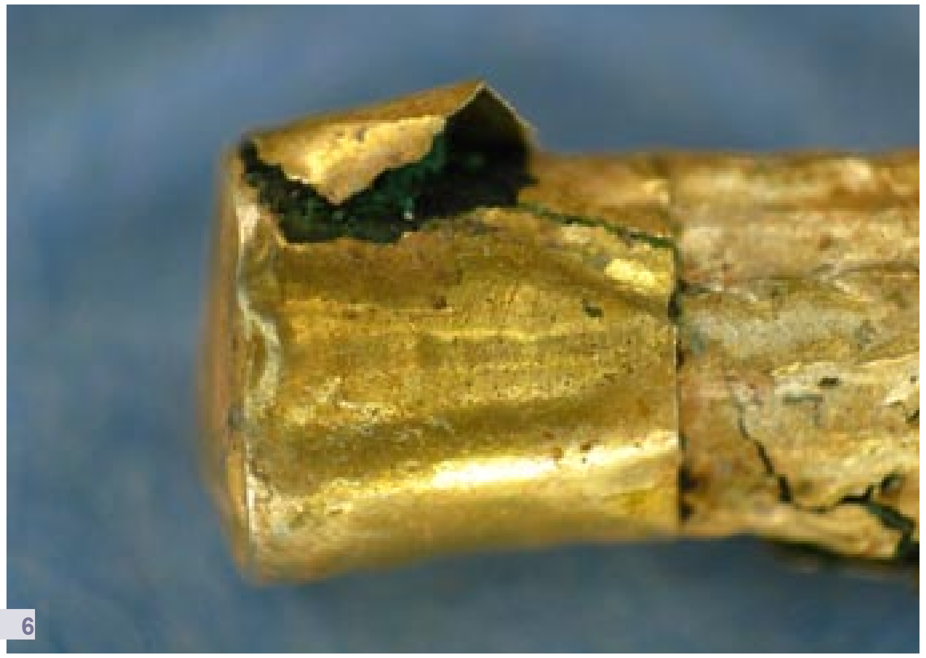


5

end cap that might correspond to the original join (see the right hand end of fig. 1). Further examination might clarify whether the side joins were soldered.

Scratches on the surface and signs of wear at the peripheries of the caps suggest that the pendant was worn in life rather than it being an object made purely for funerary adornment (fig. 3-6). The foil wrapped around the length of the pendant bears linear motifs running the length of the pendant. The motifs resemble garlands of leaves with the leaves hanging downwards towards the bottom of the pendant. This decoration was probably pressed into what is now the inner or back surface of the gold foil before it was wrapped around the copper core. It is possible that the foil was pressed into a mould to form the decoration. The decorated foil may have been fixed in place with an adhesive. In discussing the overlaying of gold on the surface of other materials such as copper alloys, Ogden states that for "thinner foils and gold leaf the easiest procedure was to glue it to the substrate – either directly to the surface or over an intermediate gesso layer" [4].

As may be seen beneath the split in the upper (right-hand) end cap in fig.1, and again beneath the torn flap of the upper end cap in fig. 2 and 4, the end cap overlaps the decorated foil that sheathes the copper core. This overlap is also apparent at the open end of the lower cap (fig.1, 2, 5 and 6). The end caps thus help to keep the decorated foil in place. The decorated foil does not, however extend beneath the caps as far as their closed ends. The fact that the decorated foil extends only a little way under the end caps is apparent in fig. 1 in the split along the side of the upper cap and (in fig. 2 and 6) from the green corrosion visible under the tear in the lower end cap.



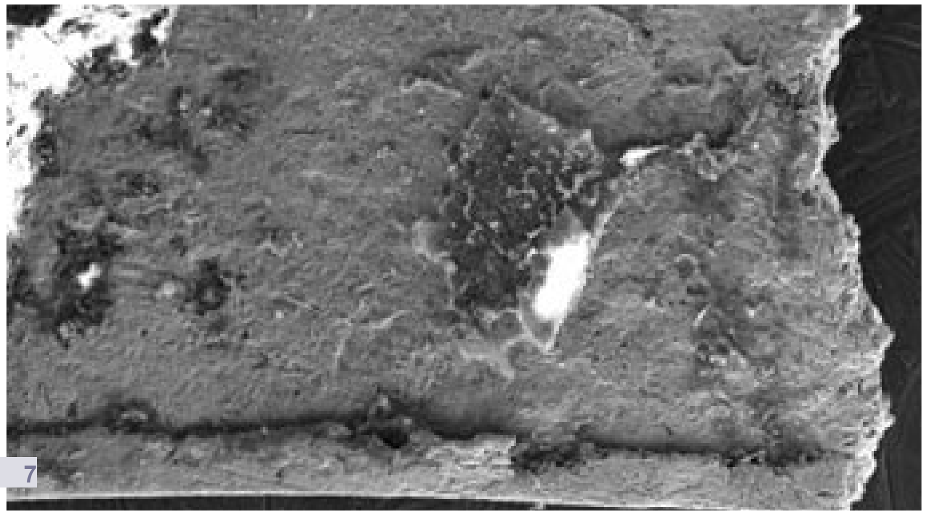
6

6 The cap at the lower end of the pendant showing a tear in the lower part of the side and the corroded copper rod beneath.

As can be seen in fig. 1, 2, 4 and 6, the end caps at each end of the pendant do not appear to have been tightly attached or soldered to the decorated sheet and may have been fixed in place with adhesive.

A tiny fragment of the foil had become detached and was loose in the sample container. Examination with scanning electron microscopy of the duller side of the fragment of foil (taken to be the inner side) showed that one edge of the foil had been folded under to make a straight edge to the fragment. (This is similar in principle to folding over the ragged cut edge of a piece of material to make a hem and a neat edge). The fold gave a far neater straight edge than the somewhat ragged cut edge of the foil still seen on the inner margin of the fold. This is very fine work as the strip folded under is only about 0.03 mm wide (fig. 7). This evidence would be consistent with the fragment

being derived from the edge of one of the end caps. The flap torn upwards to reveal the inner surface of the upper cap (fig. 4) may have an edge that is folded under. The folded straight edge of the fragment showed no signs of soldering. The end caps have very straight open ends and appear not to be soldered to the decorated sheet (see fig. 1, 2, 4 and 6). It thus seems it is quite possible that the fragment comes from the open rim of one of the end caps. Further work might serve to place these hypotheses on a firmer basis.



7

7 A scanning electron micrograph of the inner side of the loose fragment of foil showing the narrow strip of foil (about 0. 03 mm wide) folded under to form a straight edge. The field of view is approximately 0. 5 mm from side to side.

Analytical results

The above fragment of foil was subjected to non-destructive elemental analysis using scanning electron microscopy with energy dispersive X-ray spectroscopy. The shiny surface of the fragment of foil, taken to have been the outer surface, gave normalized compositions from different analysed areas ranging from 61-88 weight % gold, 11-36 wt% silver and 2-3 wt% copper. In modern jewellery terminology this corresponds approximately to 15-21 carat gold [5].

It should be noted, however, that the analytical results given above were surface analyses taken on an unclean surface, not analyses taken from a polished cross-section of the foil. It is possible that the surface may have been subject to contamination and to variable degrees of preferential corrosion during burial. These processes might make the surface composition a little different from the original bulk composition of the gold foil. It should also be noted that the composition of the alloy used to form the end caps may be different to the composition of the alloy used to form the decorated foil.

Non-destructive analysis of the inner surface of the fragment of foil showed significant amounts of copper in the duller areas, quite probably derived from the visible green corrosion of the copper core of the pendant. In some areas of the inner surface of the foil, silicon, iron, aluminium and calcium were also found: these could easily originate from soil getting under the edge of the foil. In cleaner areas of the inside of the foil, the gold content of the foil was a little lower than had been found on the outer surface. Analyses of different cleaner areas of the inside of the foil (when normalized for a gold-silver-copper alloy) gave results ranging from 47-55 wt% gold, 41-47 wt% silver and 4-6 wt% copper.

As the analyses have been conducted on unclean surfaces, it is difficult to draw any firm conclusions from differences between the results obtained from the inner and outer surfaces of the foil fragment. Some of the copper found in the analyses of both the inner and the outer surfaces of the fragment of foil may have been contamination from the clearly visible corrosion of the core of the pendant.

The apparently higher gold lower silver content of the outer surface may have been due to loss of silver from the surface during burial but it might have been due to deliberate surface treatment during manufacture. The variability of the analytical results from different areas of the outer surface should be a warning against overinterpretation. The wide range of results from different areas of the surface may suggest that postdepositional processes (which might vary on a microscopic scale) might account for the differences in composition between different but closely positioned locations: the fragment is after all very small.

Despite the above cautions, the analytical results from the fragment are broadly consistent with what might be expected from native gold. In the Middle Bronze Age gold would probably have been available from the Eastern Desert of Egypt, from Nubia and from Anatolia [6]. Natural gold deposits often contain appreciable amounts of silver (5-45 wt% [7], most commonly 8-15wt% [8]) and a little copper. Ogden states that for Egyptian gold alloys, a gold content of 70-85 wt% is most typical. Copper may be present at up to 10 wt% but some of this may be deliberately added [9]. Bachmann lists analyses of about 160 natural, native binary and ternary gold alloys ranging in composition from 49-98 wt% gold, 2-42 wt% silver and 0-4 wt% copper[10]. (These figures exclude examples where associated copper or other minerals were suspected to have been present). Bachmann considers that gold artefacts with copper contents above about 2 wt% may have had copper deliberately added to the alloy, although the unintentional inclusion of copper minerals in the analysed sample may distort the analytical results [11].

No tin was detected in any of the analyses which may suggest that the core of the pendant was copper rather than bronze. It must be noted, however, that the green corrosion products have not been analysed directly so the possibility of the core being bronze remains.

Conclusions

Given the non-destructive nature of the elemental analyses, which were conducted on contaminated surfaces rather than on polished cross-sections, caution is necessary in drawing conclusions from the analytical results. It would be reasonable to infer, however, that it is likely that the fragment of foil was made from naturally occurring gold alloy. Deliberate addition of a small amount of copper is a possibility but the copper levels detected seem quite likely to arise from the openly visible corrosion products originating from the core. It should be noted that only one tiny fragment of foil has been analysed: the decorated foil may have an alloy composition different to that of the end caps.

No tin was found in any of the analyses so it may be that the core was made of copper, rather than bronze. This is not yet certain, however, as the core material itself has yet to be analysed.

The decorated foil covering most of the length of the core had its design worked from what was to be the inner side before the foil was applied to the core. The ends of the decorated foil were protected against damage and partly held in place against the core by the enclosing end caps which were probably held in place by adhesive.

The end caps appear to have been formed by soldering a disc of gold foil (a perforated disc in the case of the upper cap) to the edges of the foil cylinders which formed the sides of the caps. Each cylinder was probably formed by bending a strip of foil. The ends of the strips may have been soldered together to make the sides of the caps, though firm evidence for this requires further work.

Comparing the circular ends of the two end caps, it would seem that while one was complete, the other was perforated, perhaps to allow the passing through one end cap of the thin metal strip whose stump is seen at the centre of one end surrounded by whitish filler (fig. 2). The fact that the core extends to the end of the cap at one end and at the other is reduced to a narrow strip surrounded by filler is also consistent with one end being designed to allow suspension. This interpretation of the surviving material remains would be consistent with the object having been a cylindrical, gold-sheathed pendant.

We do not know the true significance of the pendant but signs of wear on the end caps suggest that it was worn in life and was not made purely as an object for burial. Those who buried the occupant of burial 102 believed that it was appropriate for the pendant to remain with the body in the grave after death.

NOTES

1 H. Newman, 1981, p. 89.

2 J. Ogden, 1992, p. 52.

3 H. Maryon, 1971, p. 5-9.

4 J. Ogden, 2000, p. 164.

5 H. Maryon, 1971, p. 6-7; M. Grimwade, 1985, p. 47-62.

6 J. Ogden, 1992, p. 28-30; J. Ogden 2000, p.161-162.

7 A. I. M. Seruya Cardoso Pinto, 1986, p.125-126.

8 M. Grimwade, 1985, p. 7.

9 J. Ogden, 2000, p. 162-164; see also J. Ogden, 1992, p. 28-32.

10 H.-G. Bachmann, 1999, p. 269-270, Table 1.

11 H.-G. Bachmann, 1999, p. 269.

BIBLIOGRAPHY

H.-G. Bachmann, 1999, "On the Early Metallurgy of Gold: Some Answers and more Questions", in A. Hauptmann, E. Pernicka, Th. Rehren and U. Yalcin (eds.) *The Beginnings of Metallurgy, Der Anschnitt*, 9, p. 267-275.

M. Grimwade, 1985, *Introduction to Precious Metals*, London.

H. Maryon, 1971, *Metalwork and Enamelling*, 5th edn., New York.

H. Newman,1981, *An Illustrated Dictionary of Jewelry*, London.

J. Ogden, 1992, *Ancient Jewellery*, London.

J. Ogden, 2000, "Metals" in P. T. Nicholson and I. Shaw (eds.), *Ancient Egyptian Materials and Technology*, Cambridge, p. 148-176.

A. I. M. Seruya Cardoso Pinto, 1986, *Ageing Processes in Ancient Gold alloys*, PhD dissertation, Institute of Archaeology, University of London.