Goldwork Technology at the Arabian Peninsula. First data from Saruq al Hadid Iron Age site (Dubai, United Arab Emirates)

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ABSTRACT

The Spanish team that leads a research project at Saruq al Hadid excavated an area where about 450 gold items were recovered during the campaigns from 2015 to 2017. The site with a lengthy occupation from the end of the fourth millennium to the Islamic period is well known for its important finds attesting copper metallurgy production during Iron Age II. Other rich archaeological finds in iron, stone and pottery, in some cases showing a snake iconography, point to a ceremonial place where production processes and exchanges took place.

We present an archaeometric study of a significative sample of the gold items found at the site using OM (Optical Microscopy) and SEM-EDS (Scanning Electron Microscopy with Energy Dispersive Spectroscopy). Our provisional results suggest the existence of a workshop -the first archaeologically attested at the Arabian Peninsula- where lost wax casting and plastic deformation were usual practices, together with other goldwork techniques like polychrome alloying, filigree and granulation. Evidence of the production processes were workshop wastes and raw material, although no associated archaeological structures could be identified.

Keywords: Iron Age, Arabian Peninsula, Gold, SEM-EDS, Lost-wax casting, Polychromy

1. Introduction

Saruq al Hadid is for the time being the most important archaeological site in Dubai. With a total surface of around 7 Ha, it is located in the north prolongation of the Rub al-Khali Desert, in a live dune system (Fig. 1). The nearest modern water source is 50 km away, but on the site some water wells were unearthed. A long occupation has been attested from the Hafit period (ca. 3100-2600 BP) to the Islamic one. However continuous occupation is only documented between the Bronze Age and Iron Age II. This last period (1100-600 BC) has yielded abundant archaeological finds spread over an area of 1 km^2 buried in the dunes up to 6 m deep including evidence of smelting and casting together with finished objects in what seems a metalworking site of copper, bronze, iron and gold (Weeks at al., 2017). The wide variety of objects includes technical ceramic (fragments of furnace, furnace lining together with copper slags) soft-stone and alabaster vessels, semi-precious stone beads and ceramic vessels with a snake decoration in relief, an element that is generally associated with cultic places (Benoist et al., 2015). Other data that reinforces the hypothesis of the site not only as an industrial centre but also as a ceremonial

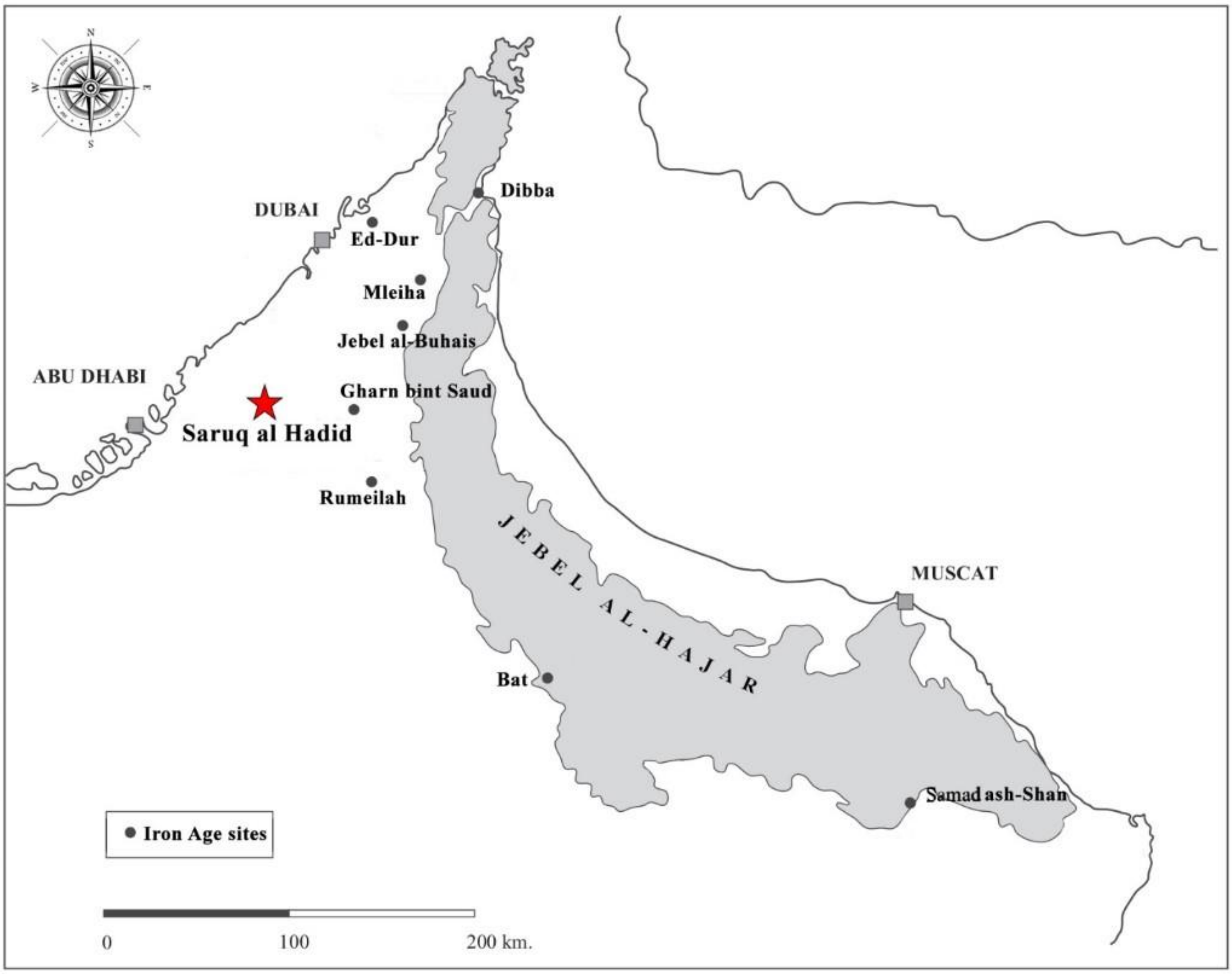

Figure 1. Map of the sites mentioned in the text in relation with Saruq al Hadid (adapted from Benoist, 2012) (1.5 columns fitting image).

place are related with the concentration and ordered disposition of some metal objects in the sand (arrow heads, axe heads, blades, iron swords), the non-utilitarian metal types attested (copper snakes, anthropomorphic figurines, miniature weapons) and the presence of cultic objects themselves and imports, for example an Assyrian or Babylonian bronze brazier (Potts 2009).
Several archaeological teams from Dubai and other countries have worked since 2002 in the place (Khraysheh and Nashef, 2007; Casana et al., 2009; Contreras Rodrigo et al., 2017; Herrmann, 2013; Herrmann et al., 2012; Nashef, 2010; Qandil, 2003; Weeks et al., 2017). A Spanish team have been working at the site from 2015 to 2018 in Area 2A. This area is located to the north-east of the areas opened by other archaeological teams.
Focussing in the area excavated by the Spanish team, over 448 gold items were recovered. These were deposited on the sandy soil and could not be associated with any archaeological structure. It should be borne in mind that displacements of material within the live dune system could occurred in Rub al-Khali Desert, and stratigraphic sequences could have not been preserved due to the Aeolic movement that remained active over time (Atkinson et al., 2011). Absolute dating with radiocarbon analysis (^{14}C) spans over a quite wide chronological time span, ranging from ca. 1200 up to 800 BC (Contreras Rodrigo et al., 2017). It should be noted that gold production wastes (drop, ingot, raw material) were recovered together with the finished objects. These data make Saruq al Hadid the only site where goldworking is attested in the Arabian Peninsula. We undertook an archaeometric study of a wide sample of these gold objects with the purpose of characterizing goldworking processes under the hypothesis of the first gold workshop in the region. There are some restrictions to full achieve our target among which the absence of analytical data concerning gold objects in the Arabian Peninsula as well as the absence of technological studies of the production processes or manufacturing techniques. Traditionally gold objects were characterized from the typological point of view and raw materials identified under visual observation. This situation contrasts with better known areas of the Near East such as Iran, the Levant (Maxwell-Hyslop 1971; Duval et. al., 1989; Wooley 2006; Prévalet, 2010, 2014), and particularly Egypt (Lemasson et al., 2015; Troalen et al., 2014).

2. Materials and methods

About 80 gold items have been studied by optical microscopy (OM) including 1 fusion droplet, 1 fragmented ingot and 9 waste pieces or semi-finished products (fragments of wire and sheets). The rest are jewellery products. 14 of these finished items have been chemically analysed by SEM-EDS (Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy). Sampling was determined by administrative and budget restrictions to a large extent. However we consider the selected objects an accurate approach to the jewellery found at the site from the typological point of view. All the items come from layers dated to the Iron Age II, they were deposited directly on the sandy soil, and could not be associated to any archaeological structure. From the functional point of view the gold set could be described as adornments. These are beads, earrings and appliqués comprising a variety of types. In this sample we have identified 14 types, clearly differentiated by their formal and metrical characteristics as presented in Fig. 2. Table 1 summarises their description and related data.

The typological set studied in this paper is not the overall jewellery recovered at the site but its main part. Other objects like star-shaped beads, biconvex globular beads, conical shaped earrings, figurines or miniature weapons appear to a much lesser extent (Khraysheh and Nashef, 2007; Weeks et al., 2017).

Optical microscopy (OM) has been used to characterize use-wear and tool marks on metal surfaces. We used portable binoculars at the site (mod. CETI 1-4.5x), a facility of the Dubai Municipality. We follow the methodology proposed by Gutiérrez and Soriano (2008) and Perea and García-Vuelta (2012).

Figure 2. Type Classification of gold objects (colour online) (2 columns fitting image).

Object	**Description**	**Length (mm)**	**Width (mm)**	**Height (mm)**	**Nº of doc. (1st and 2nd)**
Cylindrical bead	Rolled up sheet. Straight profile	3 - 5.5	3 - 5.5	2 - 3	24
Tire shaped bead	Donut shaped sheet. Convex profile	4 - 5	4 - 5	2	4
Barrel shaped bead	Cylinder shaped bead	2.5	2.5	2.5	3
Annular bead	Opened ring. Convex profile	4	4	1	2
Flower shaped bead	Petal shaped prills arranged in a circle. Composite profile	6.5	6.5	2.5	1
Simple grain bead	Grains arranged in a circle. Composite profile	3.5 - 4.5	3.5 - 4.5	1 - 2	47
Double grain bead	Grains arranged in two circles, one above the other. Composite profile	3.5 - 6.5	3.5 - 6.5	1.5 - 2	18
Cylindrical grain bead	Grains arranged in a cylindrical shape. Composite profile	4.5 - 7.5	4.5 - 7.5	10 - 11.5	8
Simple concentric grain bead	Inner ring of several continuous globules and outer ring with intervals between each globule	4.5 - 10	4.5 - 10	1	17
Double Concentric Grain bead	Grains arranged in two concentric circles, and one above the other. Composite profile	7	7	1.5	5
Crescent shaped earring	Two-horned ring	22 - 24	13.5 - 22	7 - 11.5	5
Hook earring	Strip arranged in an elongated opened ring	9.5	6	1.5	1
Calotte	Fragmented sheet hemisphere	7	6	2.5	1
Sheet appliqué	Appliqué decorated made of sheet	-	-	-	2

Table 1. Description of the gold items from Saruq al Hadid examined by OM.

The analyses were carried out directly on the piece, without any previous treatment, at the express request of the Dubai Municipality. One of the major conditioning factors of surface analysis with SEM-EDS is the sensor's low penetration capacity, which makes it very sensitive to surface heterogeneity, such as those due to corrosion or deliberate surface treatment processes. (Troalen et al., 2014). However, most analyses carried out in this study have values above 80% Au, so they are practically corrosion-free. In the remaining samples, selected non-corroded surfaces have been analysed.

Chemical analysis were performed at the Microscopy Services of the Autonomous University of Barcelona, using a Zeiss Evo ® MA10 equipment provided with an EDS Oxford Linca detector and a second equipment, a Zeiss Merlin FE-SEM with an EDS Oxford Linca X-Max detector. The EDS detectors use INCA® software from Oxford Instruments. The L_a series of gold and silver and the K_a series of copper have been quantified using default INCA ZAF correction.

Following the protocol of Adeva and González (2004) as a guide, we have worked with an energy of 20 KeV, and the dead times of the detector ranged between 20 and 25%. As for the acquisition time of the analyses, priority has been given to working with exposure of 100 and 150 seconds, depending on the irregularity of the area to be analysed. However, due to equipment availability issues, some measurements are just 30 seconds long. In the former cases, the values in Table 2 should be considerate as estimative.

Results, shown in Table 2, are the normalised mean (to 100%) of measurements expressed in "Nº of measurements" column. In each case, the highest error rate of the different analyses carried out was taken as a reference. Area measurements have been prioritized, although in some cases such as narrow joints, spot measurements have been used. The aim has been to characterize the wider possible area in each measurement. Results are discussed in Sections 3.1 and 3.2.

Data crossing between OM and SEM-EDS allowed us to determine the manufacturing processes in most cases. Our study reveals complex technological processes and manufacturing techniques depending on the different types of item. Results are summarized in Table 3 and discussed in Sections 3.2 to 3.4.

Concerning beads, the most numerous group of the sample, we must take into account its wide geographical and chronological spread over the Near East. As an example, it is well known the high number and variety of different beads found in the famous Trojan Treasure A (Antonova et al. 1996) or those found at the necropolis of Tell Fara (Iraq) and Tell el-Ajjul (Gaza) (Maxwell-Hyslop 1971: 227). It would be tempting to think in diffusionism, through time and space, to explain the beads at Saruq al-Hadid but a comparative study shows great differences between these Near Eastern beads and those from our site, both in shape as in manufacturing procedures. Definitely they are not comparable, in addition to the chronological gap. This is one of the reasons to consider the hypothesis of a goldwork local/regional production at Saruq al-Hadid with its own personality.

Excavation No.	Type	Observations	Nº Measurements	Time sec.	Au %	Ag D. ST	Ag%	Ag D. ST	Cu%	Cu D. ST
1395_10	Barrel shaped bead	External surface (All)	5	100	97.5 ±0.34	0.25	2.0 ±0.22	0.15	0.4 ±0.15	0.18
1396_03	Cylindrical bead	External surface (All)	3	100	95.3 ±0.3	1.02	4.0 ±0.20	0.95	0.7 ±0.14	0.13
1405_11	Simple Grain bead	Grains (external face)	5	150	94.3 ±0.86	2.20	5.3 ±0.71	2.20	0.4 ±0.23	0.38
1405_11	Simple Grain bead	Junction (front zone)	1	150	96.6 ±0.74		2.5 ±0.60		0.8 ±0.45	
1405_11	Simple Grain bead	Wide Junction	1	30*	92.6 ±1.76		6.4 ±1.52		1.0 ±0.96	
1405_11	Simple Grain bead	Narrow Junction	1	30*	81.2 ±1.96		17.1 ±1.81		1.7 ±0.97	
1405_44	Bended sheet	External surface (All)	2	100	26.4 ±0.37	0.67	72.0 ±0.41	0.45	1.6 ±0.17	0.23
1405_73	Embossed sheet	External surface (All)	3	100	78.0 ±0.4	1.17	18.9 ±0.35	0.96	2.8 ±0.21	0.21
1412_02	Barrel shaped bead	External surface (All)	4	150	86.9 ±0.3	0.84	11.7 ±0.23	0.99	1.4 ±0.15	0.22
1412_04	Filament	External surface (All)	5	100	48.6 ±0.73	0.38	50.2 ±0.7	0.56	1.2 ±0.32	0.47
1412_08	Annular bead	Generic (All)	4	150	49.8 ±0.31	3.22	48.0 ±0.31	3.59	2.3 ±0.15	1.01
1412_19	Double Grain bead	Grain	3	150	75.4 ±0.30	2.40	22.8 ±0.25	2.51	1.7 ±0.13	0.28
1412_19	Double Grain bead	Junction	2	150	74.0 ±0.34	2.24	23.8 ±0.28	2.43	2.2 ±0.16	0.18
1414_01	Double Concentric Grain bead	Top row grain	1	150	84.4 ±0.25		14.2 ±0.2		1.4 ±0.12	
1414_01	Double Concentric Grain bead	Bottom row grain	3	150	70.6 ±0.29	2.09	26.3 ±0.25	1.68	3.1 ±0.14	0.51
1414_01	Double Concentric Grain bead	Grains junction	2	150	60.8 ±1.00	2.62	29.6 ±0.8	1.12	9.6 ±0.48	1.49
1414_20	Simple Grain bead	Junction	1	150	85.0 ±0.52		13.4 ±0.35		1.6 ±0.26	
1414_20	Simple Grain bead	Grain	1	150	89.3 ±0.39		9.9 ±0.26		0.8 ±0.16	
1416_03	Double Grain bead	Grain	5	150	95.7 ±0.25	0.41	3.6 ±0.16	0.38	0.7 ±0.13	0.09
1416_03	Double Grain bead	Junctions	5	150	92.9 ±0.23	1.48	4.7 ±0.15	0.8	2.4 ±0.12	0.73
1397_04	Simple Grain bead	Grain	3	30*	77.1 ±1.21	1.69	21.0 ±1.1	0.97	2.0 ±0.62	0.73
1397_04	Simple Grain bead	Junction	1	30*	72.9 ±1.02		25.5 ±0.95		1.7 ±0.48	

1405_54	Simple Grain bead	Non corroded Grain	6	30*	33.0 ±2.60	1.36	67.0 ±2.65	1.36	nd	
1405_54	Simple Grain bead	Corroded Junction	1	30*	nd		44.4 ±1.59		55.6 ±1.64	
1405_54	Simple Grain bead	Corroded grain	1	30*	nd		12.6 ±1.02		87.4 ±1.59	

Table 1. Description and data belonging gold objects analysed by SEM-EDS. Results normalised to 100% weight. Nd: Not detected.

What we call crescent shaped earring is a very peculiar typology and we are not sure if it was used indeed as an ear ring. Its shape seems to refer to the sacred Horns wear as a headdress by gods and goddesses figurines as well as in stone reliefs in Mesopotamia during the Bronze Age. It is well known the bronze statue of the goddess Lama, now at the British Museum (Maxwell-Hyslop 1971: 85, fig. 57), or the gold pendant in the Dilbat necklace of the Metropolitan Museum representing a goddess with a multi-horned headdress (Maxwell-Hyslop 1971: 89, pl. 62). The horns are related to representations of bulls, like the copper bull head in metal excavated under Barbar Temple II at Dilmun (Bahrein) now at the Bahrein National Museum (Caspers 1971). Probably it is through Dilmun (Bahrein) -the hub that connected Mesopotamia and the Indus Valley- that this iconography reached Saruq al-Hadid.

Unfortnately the crescent shaped earring was not analyzed due to administrative restrictions. Apparently it could be a silver gilded object but we are not sure at all, so it will be necessary to check this in future studies.

3. Technological discussion

3.1. Alloys and Gold polychromy

Our analyses show the use of ternary Au-Ag-Cu alloys with different amounts of silver and very low copper (Tab. 2). Silver content ranges between 2% and 50%, while copper has a more restricted distribution between 0.4% and 5%. In a first instance we could consider they were using natural alluvial gold based on the low copper percentages. Silver concentrations in native gold vary from almost nil to about 40-50% and up to 1% of copper content would be expected (Antweiler and Sutton, 1970; Raub, 1995). As an exception we have two samples of high silver content, c. 70% (No. 1405_44 and 1405_54).

These results open up the hypothesis of intentional additions of copper or silver to obtain different gold colours, from yellowish to reddish to whitish (McDonald and Sistare, 1978), maybe for aesthetical reasons more than metallurgical/functional ones. Except the silver bead (No. 1405_54), all the samples show a narrow range of melting temperatures (950-1050 ºC) indicating that the different alloys probably were not related with this feature (Fig. 3).

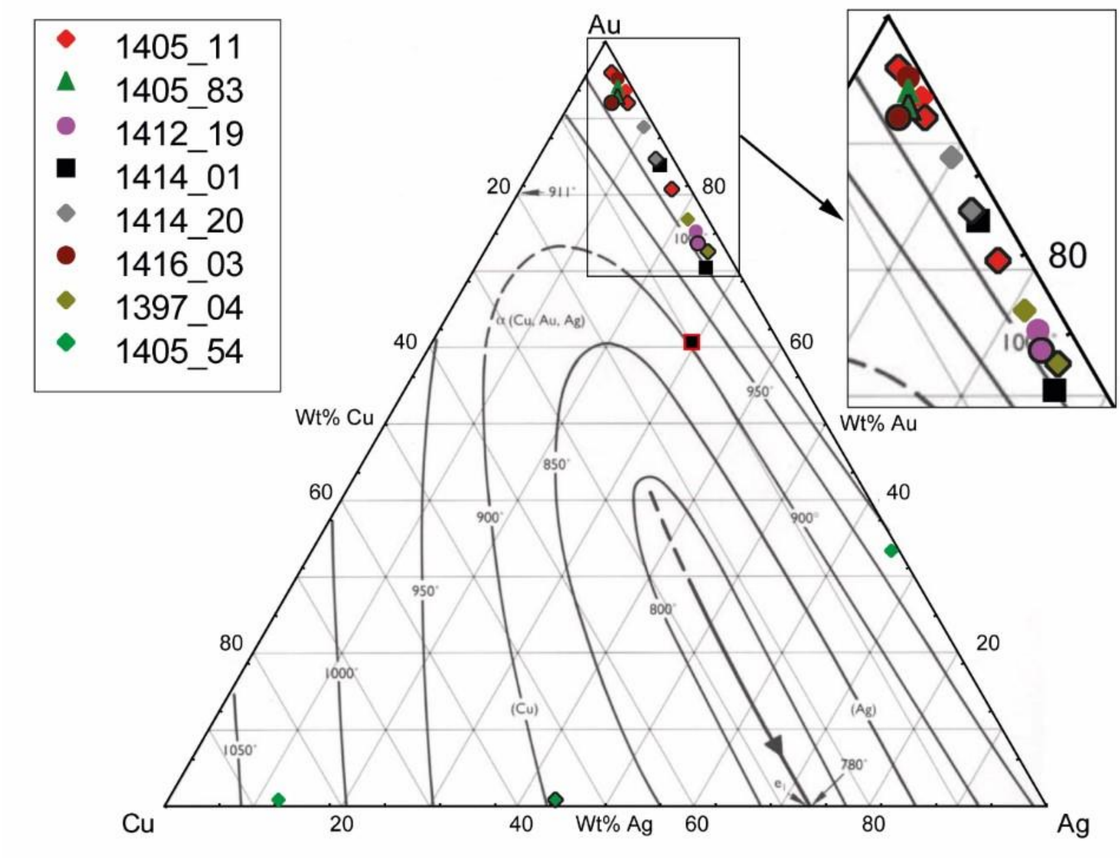

Figure 3. Ternary diagram of a selection of globular gold beads from Saruq al Hadid with representation of melting points. The analysis of the joining zones in the same piece is distinguished by a contour of a different colour. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article) (2 columns fitting image).

We must take into account two particular cases, beads No. 1414_01 and 1405_54 (Fig. 4) with an average of 20% Ag in the first case and near 65% Ag in the second, although the latter is very much corroded. They both stand out for the high copper concentrations detected in the union areas between globules which is coherent with a brazing joint using an alloy of lower melting point or at least copper salts to induce local fusion (Wolters, 1983). Nevertheless this explanation contradicts the lost wax technique detected in the manufacture of most of the beads. A third issue is bead No.1414_01 with higher copper and silver contents in the union areas which could be evidence of a brazing technique to join the globules although the surface shows the typical fine porosity of a cast object (see below). By the moment this is an open discussion because the data we manage is very scarce, so we must be cautious especially taking into account that the analytical results of the bead No. 1405_54 should be considered a rough approximation to the face value due to short time measures. Nevertheless it is difficult to explain the detection of up to 50% Cu, together with silver but no gold, in the corroded union area of one of the granules while in uncorroded granules we detect 70% Ag plus 30% Au and no copper whatsoever.

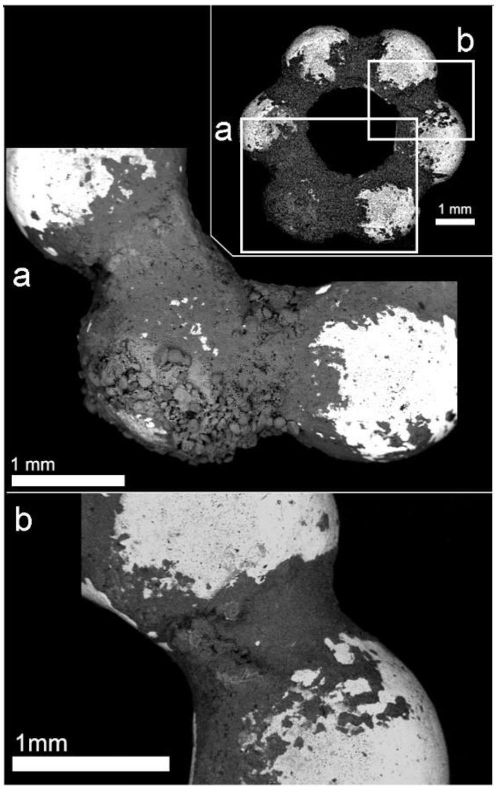

Figure 4. Backscattered electron image of No. 1405_54 corrosion of copper and silver in junctions and in bottom granule (1 column fitting image). White zones correspond to non-corroded Au rich grains.

Concerning polychromy most objects show gold and yellow hues. Only two (No. 1401 and No. 1412_19) are green-yellow and two others (No. 1412_08 and No. 1412_04) fall into a pale greenish yellow area, near the whitish-silver coloration. Finally, an isolated bended sheet (No. 1405_44) falls in the margins of a whitish tonality. We cannot dismiss the hypothesis that these two latter objects were used to increase the amount of silver during the production of other golden items (Fig. 5). We must also consider the practice of some kind of experimentation with the raw material properties to modify gold colours.

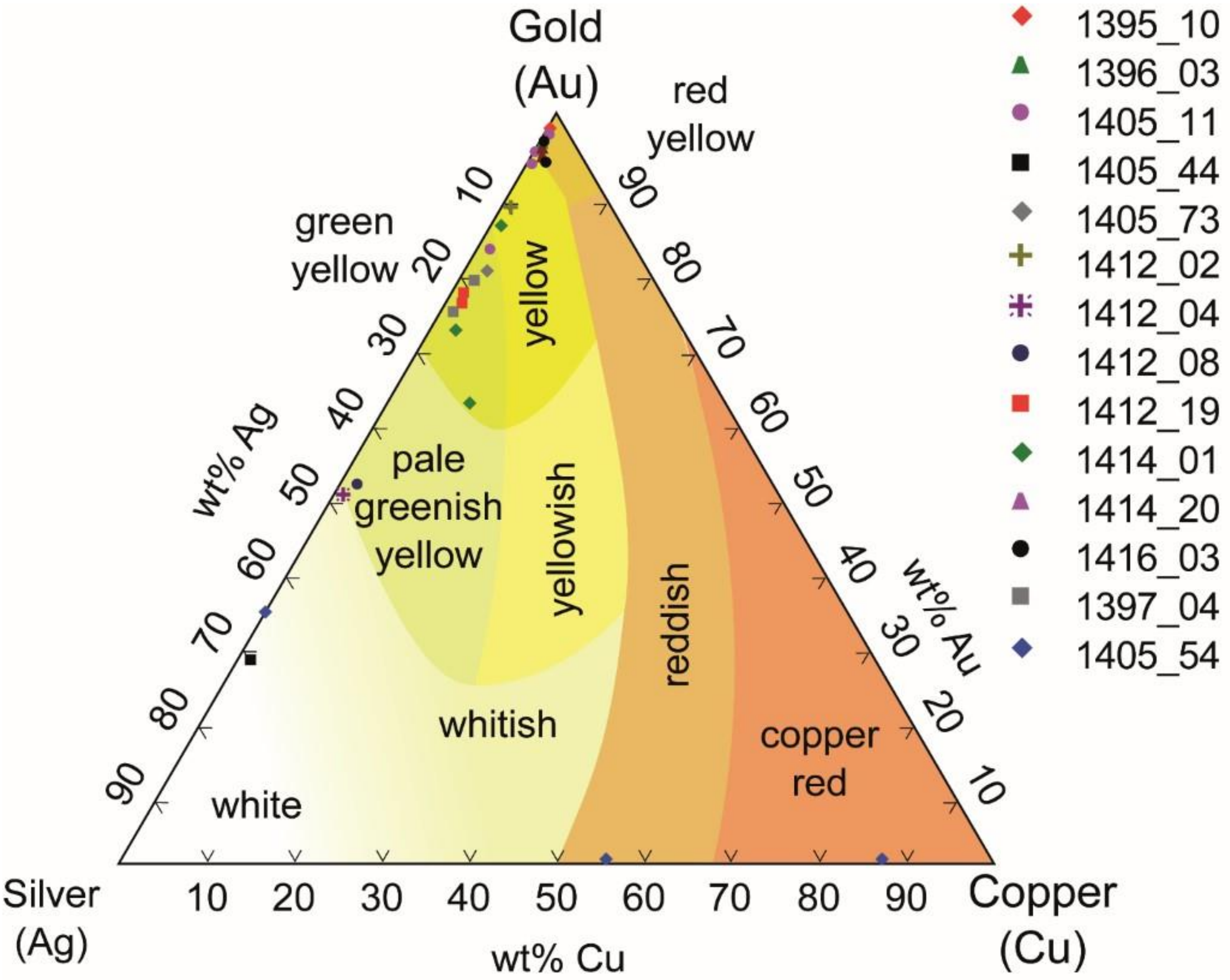

Figure 5. Gold copper-silver ternary diagram with gold colours representation. Analysis of gold objects from Saruq al Hadid plotted (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article) (2 columns fitting image).

3.2. Lost-wax casting

Lost wax casting was used to produce most part of the items we have studied -with the exceptions indicated above- including the majority of beads, mainly grain types but not only these (Table 3). Evidence, as observed in the image mode of the SEM, includes microstructure features coherent with the use of lost-wax casting, for example, fine porosity in the surface of the beads (Fig. 6); dendritic structures resulting from fast cooling of the molten alloy (Fig. 7); absence of tool marks suggesting other fabrication techniques. Porosity appears when the gas produced during the process of heating and cooling cannot be absorbed by the mould or due to an inadequate situation of the evacuation channels. A peculiar feature is the supposed careless wax modelling of the globules in the grain beads; they present irregularities and facets that could be the result of a mass production process or an intentional feature. Last but not least is the different modelling of the wax

Object	Fabrication process (excluding first casting and finishing)
Cylindrical bead	CR+PS
Tire shaped bead	LW
Barrel shaped bead	LW
Annular bead	CR+PS
Flower shaped bead	LW
Simple Grain bead	LW
Double Grain bead	LW
Cylindrical Grain bead	¿LW?
Simple Concentric Grain bead	LW
Double Concentric Grain bead	LW
Crescent shaped earring	CS+PS
Hook earring	CR+PS
Calotte	CR+PS
Sheet appliqué	CR+PS(+F+S)

on the outside and in the inside which is significant in some of the items like the bead No. 1412_19. The as cast microstructure of the inside surface is a proof that the bead was lost wax casted and it was never used (Fig. 8).

Table 3. Production techniques documented in each type on gold jewellery studied (CS=casting in object shape mould, CR=casting in rod mould, LW=lost-wax technique, PS= plastic shaping technique, G=granulation, F=filigree, S=soldering).

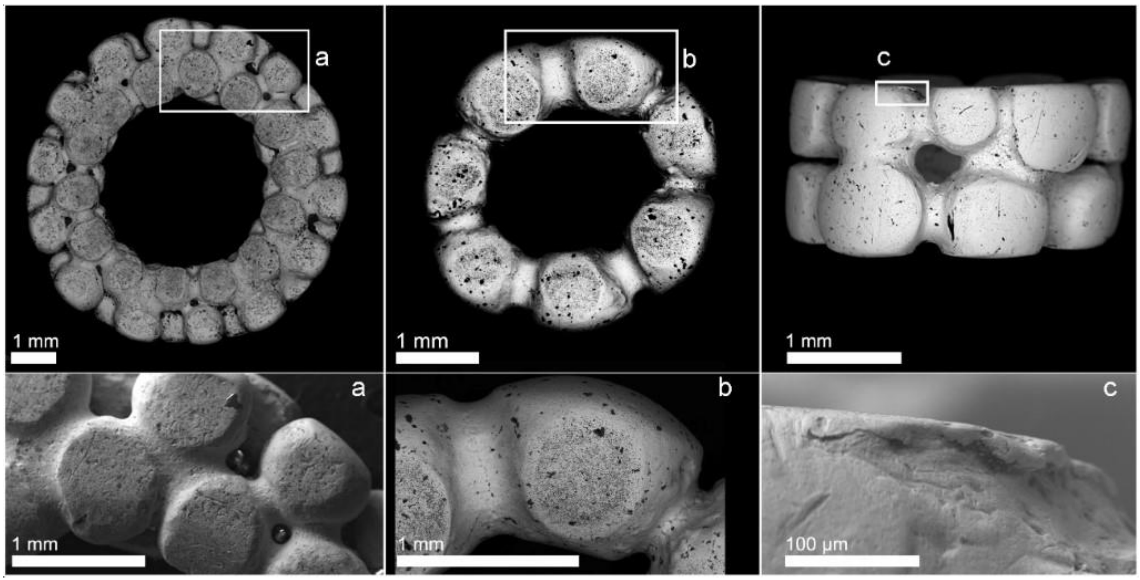

Figure 6. Backscattered electron images of lost wax casted gold beads showing porosity in the surface (Samples, a: No. 1414_01: b: No. 1405_11: c: No. 1416_03).

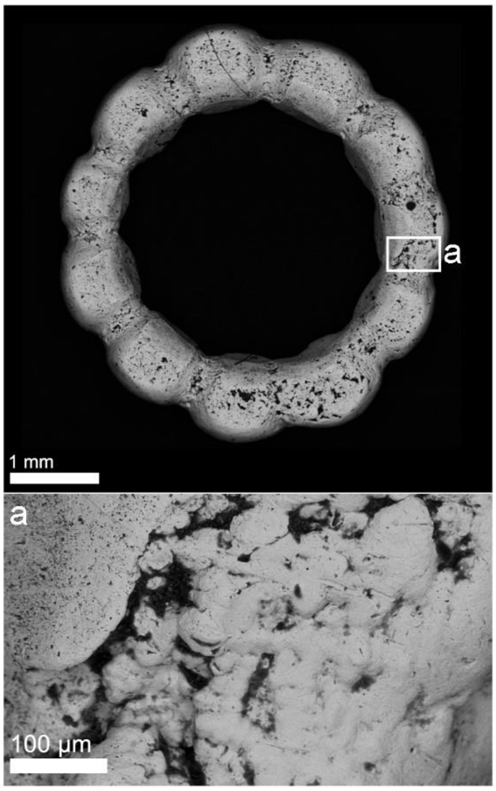

Figure 7. Backscattered electron image of a gold bead showing dendritic structures (No.: 1397_04).

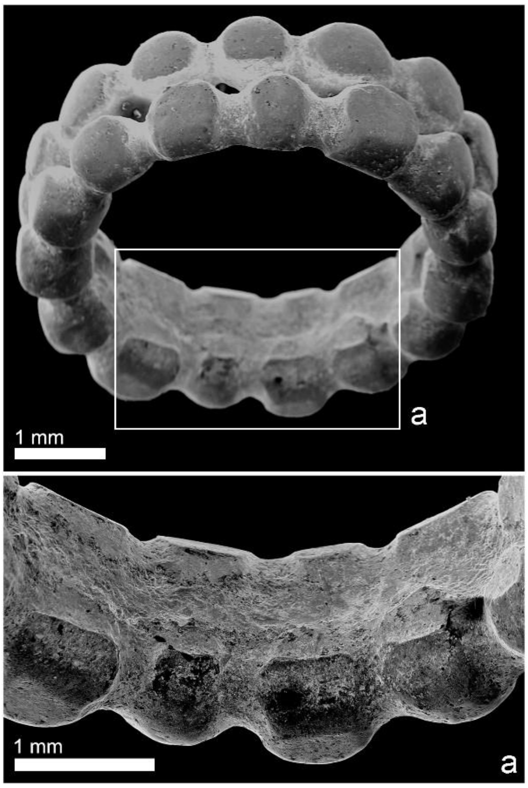

Figure 8. Secondary electrons micrographs of a gold bead with an as cast microstructure on the inside and a globulated topography in the outside (No.: 1412_19).

3.3. Plastic shaping techniques

The use of plastic deformation has been attested to work foils/sheets, wires or massive objects. Semi-finished products like sheets were used to produce cylindrical beads and appliqués. Likewise thick wires were used to manufacture annular beads and hook earrings. Fine wire, as required for filigree, was obtained by twisting a fine strip of foil as documented in some sheet appliqués. Throughout these plastic deformation processes annealing was repeatedly necessary to avoid sour metal, which means brittleness and cracking.

Sheet objects were sometimes joined by burnishing. This is not an easy technique for it requires a careful handling of minute tools and working areas, in addition to perfect cleaning of the metal surface in the areas where the sheets overlap. The joining line is only visible in few cases. For example when there is access to the cross section of the overlapped area we observed a characteristic slimming as a result of an excessive burnishing, as in some beads.

Plastic deformation was also used to modify or improve a previously casted form as in the crescent shaped earrings. Hammering traces were observed specially to modify the curved areas, probably to obtain the size required. Different hammering traces are clearly visible along the surface of some earrings; some are small circular depressions and can be related with the specific morphology of the hammer; others look like parallel oriented cramped grooves over the entire surface (Fig. 9). These were probably the result of removing casting leftovers or to smooth surfaces. Both working traces were experimentally recorded and detected in prehistoric copper-based objects (Armbruster et al., 2003: Gutierrez and Soriano, 2008).

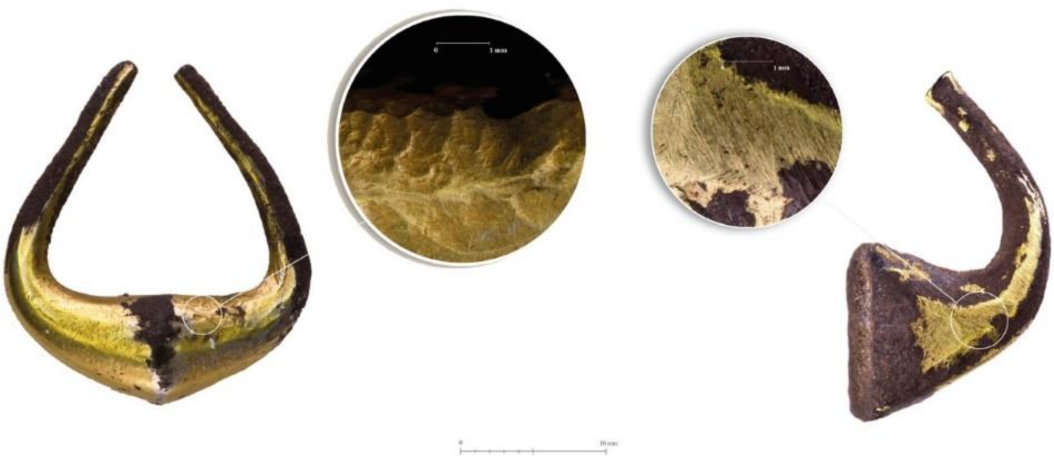

Figure 9. Crescent shaped earring and details of the associated small circular depressions and parallel cramped grooves (colour online) (2 columns fitting image).

We have evidence of gold wastes or semi-finished products worked by plastic deformation. Wire rolled in a spool, fragments of wire and half-cut sheets for the fabrication of hammered objects, annealing and subsequent cutting. Cutting was achieved with a sharpened and hard tool either a simple blade of flint or a copper or iron knife. The thickness of some of these sheets coincides with that of the sheet beads, indicating its possible use for their manufacture. Other wires or sheets could be used in different decorative techniques attested at the site (see Section 3.4).

3.4. Ornamental techniques: punching, filigree and granulation

Punching, filigree and granulation are attested in some sheet appliqués and fragments of undetermined jewellery that were not analysed by SEM-EDS (Fig. 10). We must emphasize that these techniques are very scarce.

Figure 10. Sheet appliqués. Rows of filigree (left) and spirals in wire and granulation (right) (colour online) (2 columns fitting image).

Punching or embossing is a simple decorative method based on plastic deformation, generally used in combination with repoussé work. It was attested in a fragment of sheet appliqué with a line of circles.

Filigree was used in the ornamentation of three objects found at the site. It is a complex technique based on the soldering of fine gauge wires to a base sheet. Filigree wires use to show a helicoidal seam all along their surface generated by the procedure of twisting a thin strip of gold sheet (Ogden, 1991, 1992). This was a *worldwide* technique practised during Prehistory and Antiquity. Figure 10 shows a fragment of silver wire rolled in a spiral with a clear helicoidal seam on the surface of the wire. This same fragment presents a top globule at the centre. Granulation is based in the same idea as filigree but instead of using wires the ornamental pattern is designed with very small spheres or globules. It is normally used in combination with filigree. The method to produce globules is not a difficult task due to the surface tension of fluids (Wolters, 1983; Perea, 2010). Both filigree and granulation necessarily implies the knowledge of soldering, which means controlling temperatures and the different melting points of the alloys (Guerra and Calligaro, 2003). Future analysis will be targeted to detect the specific soldering techniques used in these objects.

3.5. Melting gold and raw material supply

A fusion droplet and a fragmented ingot are direct evidences of gold casting at the site (Fig. 11). The droplet measures approx. 1 cm long and 1 mm thick and has an irregular topography. The upper face is bristly whereas the down side is smooth. This particular shape is characteristic of the cooling of a small amount of metal at the bottom of a crucible during a casting process, although no crucibles were found in this particular section of the site.

Figure 11. Direct evidences of casting: gold drop (upper) and cut ingot (below) (colour online) (1,5 columns fitting image).

The fragmented ingot measures approx. 1 cm long and 4 mm thick and has an irregular shape with a slightly convex section. This fragment shows clear casting flashes and the cutting marks indicate that it was divided in two halves.
Provenance studies through chemical analysis were not undertaken due to administrative and access restrictions. By the moment we can only guess the possible gold sources in the region according to the data currently available. No gold deposits are known from the United Arab Emirates (UAE) and only at the Sultanate of Oman there are some indications of their existence. Weeks (2000) affirms that some metalliferous deposits of Al-Ajal (zinc-copper mineralizations) at the Oman Mountains present high gold and silver concentrations. The geological characteristics of this region show high potential for the formation of gold placer deposits. Recent provenance studies by LIA (lead isotopes analysis) points to a probable extraction of the Omani copper for export, as in the case of the Egyptian Ramesside workshops dated to before the 12th century BC (Rademakers et al., 2017). Another possibility is a Harappa site from the Indus (c. 2600-1900 BC) (Hoffman and Miller, 2009). Tablets with cuneiform inscriptions from the late 3rd and early 2nd millennium BC indicate that a part of the Mesopotamian copper came by trade from Magan, a region identified with the current United Arab Emirates (UAE) and partly the Sultanate of Oman (Potts, 2012). In our case, it is possible that gold was extracted for trading with any of the aforementioned states while using it for internal consumption at the same time. Nevertheless other regions cannot be excluded. Iron Age exploitation of gold mines at north-western Yemen (Al Maraziq area) is attested, possibly related to the Egyptian State (Mallory-Greenough et al., 2000). Paleo-placers are also documented at the Harad and Hofuf areas in North-Eastern Saudi Arabia and South Qatar (Nasir et al., 2007) while different types of gold deposits are attested at Western Saudi Arabia (Arabian Shield) and Iran (Jansen et al., 2016). Ongoing research is still at its inception.

4. Conclusions

Gold objects abound at the Arabian Peninsula but Saruq al Hadid is the first workshop where gold was manufactured into jewels attested archaeologically. The presence of casting wastes and the raw material itself is evidence enough although we still ignore the origin of the raw material. Concerning production processes we have identified numerous sheets and wires, in some cases with cutting marks, indicating their use as pre-products in the direct manufacture of jewellery.
The attested goldwork techniques are diverse and complex, some of them requiring skilled artisans with high expertise. Lost-wax casting especially but also plastic deformation were the basic and most used manufacturing processes, while punching, filigree and granulation were used as ornamental techniques in few of the remains. Different gold alloys were intentionally prepared to obtain different colours of the jewellery produced. Most of these techniques were in use at an earlier

date in the nearby regions that's why external stimuli or transfer is a possibility to explain technological change. For example gold polychromy had a long tradition in Egypt and the use of variable amounts of copper and silver to modify colours is attested from the Old and Middle Kingdom (ca. 2700-1800 BC) to the 2nd Intermediate Period (ca. 1800-1550 BC) and the New Kingdom (ca. 1550-1070 BC) (Aldred, 1971; Wilkinson, 1971; Lilyquist, 1994; Troalen et al., 2014). It is usually thought that granulation originates in Syria during the Early Bronze Age (late 3rd millennium BC) and some examples of this technology are known from Iran at the 2nd millennium (Wolters, 1983; Duval, Eluère and Hurtel, 1989). The joint use of filigree and granulation is attested in Syria, Anatolia and Mesopotamia at the end of the 3rd or beginnings of the 2nd millennium BC and in Egypt during the Middle Kingdom (c. 2000-1800 BC) (Prévalet, 2014). In relation to soldering techniques, brazing is attested in Easter Mediterranean at the second half of the 4th millennium BC and in Egypt from the Early Dynastic Period (c. 3400-2900 BC). Colloidal unions were first used at the end of the 3rd millennium BC in the Levant and Mesopotamia, while in Egypt it is documented only from the New Kingdom (Prévalet, 2010). The connection between the Arabian Bronze Age and the Iron Age of nearby regions is well attested (Magee, 2014). Regional contacts with Mesopotamia, Assyria, Egypt, Iran and India are demonstrated by some pottery types, metal objects (vessels, swords, braziers), stamp seals, personal adornments (carnelian beads, decorated discs) and textual data (Potts, 2012, 2016). Nevertheless more research on technological procedures and manufacturing techniques is needed to establish a chronological sequence of these processes and the distribution or influences between these regions.

We interpret the site of Saruq al-Hadid as a production and distribution centre of manufactured gold for the whole region. The scenario we suggest for the site is a workshop where raw gold came from abroad. Here it was melted, casted and worked to produce jewellery. The finished product would be distributed among the different groups and/or settlements involved in the exchange/trade relations.

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