Originalveröffentlichung in: I.V. Zaitsev (ed.), Arabian Antiquities studies dedicated to Alexander Sedov on the occasion of his seventieth birthday, Moscow 2020, S. 285-294

Paul A. Yule
(Heidelberg)

Gold beads of the Samad Late Iron Age, Sultanate of Oman

Key words: Late Iron Age, gold beads, granulation, Deutsches Bergbau-Museum, Samad al-Shan

Alexander Sedov, to friends and close colleagues, Sasha, has been a constant and redoubtable figure in Arabian archaeology for nearly 40 years. His knowledge of the pottery, numismatics and archaeology of southern Arabia is authoritative. I thank him especially for encouraging me in 2011 to publish the pottery excavated from Ẓafār/Yemen, when I hesitated.

One of the most striking finds to be excavated from the multi-period cemeteries at Samad al-Šaʾn in the eastern central part of Oman (Fig. 2) is a suite of gold beads which came to light in the Late Iron Age grave, S100841, together with others (Figs. 3 and 4). During the excavation season of 1991 they were inventoried as number DA 12235. The beads appear in the report catalogued, as drawings and as a colour photo (Yule 2001 I: 270, cat. no. 10; II: Taf. 175.10, 564d), but their technology and condition were hardly discussed. Although the reconstructed necklace under discussion is the pride of the National Museum in Muscat (al-Moosawi et al. 2016: 43), it is little known among Arabianists. One reason for this is, as in mainstream ancient Near Eastern archaeology, most archaeologists focus on the Bronze Age, not the late period. Today, the Samad Late Iron Age (LIA, <100 BCE–300 CE) is known from some 87 sites, mostly cemeteries (Fig. 2). These lie scattered over some 17.000 km^2, about the same surface area as Kuwait. What a conservationist strung as a necklace (see below) brings to mind the difficulty of the definition of the still little-known Samad assemblage: the beads were not locally manufactured but rather are imports from outside. Data are still lacking for any kind of metal production or working for its population. Gold was not extracted from ore of south-east Arabia until recently. Four aspects form the following note: 1) find circumstances, 2) bead description and optical microscopy, 3) manufacturing technique, REM (reflection electron microscope) results, 4) archaeological comparisons. 29 years after the excavation closed we can further illuminate this striking find.

1. Find circumstances

A LIA grave of Samad type yielded a large collection of beads (Figs. 4 and 6) which presumably once were worn as one or more necklaces. The find situation is described in the following manner: "The skeleton was pushed and no longer in anatomical connection. Just above the floor in the south-eastern corner lay disturbed several objects, partly in the interstices between the stones of the walling.... In the chest area between the bones numerous beads lay, of gold, carnelian, glass, silver and agate (find 10). The beads lay scattered on the rough floor of the grave. All lay between the bones in a 4 cm thick layer" (U. Hartung in: Yule 2001 I: 270). Perhaps the reason that the beads survived is that the scavenger did not recognise them inside the dark, roofed grave chamber. Also, perhaps they were mixed into and not on the sediment of the grave floor.

2. Bead description and optical microscopy

Inventory of gold beads

Granulated double spherical beads connected by soldered granules:

surface condition *a* —	19 pieces
surface condition *b* —	7 pieces
surface condition *c* —	5 pieces
	31 pieces

Single spherical beads:

surface condition *a* —	21 pieces
surface condition *b* —	8 pieces + 2 fragments
surface condition *c* —	4 pieces
	33 pieces + 2 fragments

Flat single bead with a large hole (not shown):

surface condition *b*

Total: 66 pieces

In Bochum in 1991, the gold beads were examined with an 8x microscope which revealed different accretions to adhere to the bead surfaces possibly due to different storage conditions in the soil beside adjacent grave goods:

surface condition *a* — surface covered with thin, sandy, light deposits
surface condition *b* — surface covered with a thin, smooth, reddish layer; sandy deposits above
surface condition *c* — surface covered with a thin, smooth, blackish layer; sandy deposits above.

Dimensions of double beads (Fig. 1a): H — 9.8–10.1 mm, H_1 — 3.0–3.3 mm, H_2 — 5.8–6.0 mm, W_1 — 3.5–4.0 mm, W_2 — 6.0–6.3 mm, ø perforation — 0.9 mm. Width is measured parallel to the perforation. Height is measured perpendicular to it.

Single beads: same size as upper sphere of the double beads, flat bead (not strung): H — 5.1 mm, W — 3.0 mm, ø hole — 1.9 mm.

31 extant double gold beads (I–XXXI) consist of a smaller sphere above made of two pierced joined halves. The lower, larger sphere is manufactured the same way. The seam of the upper sphere is vertically oriented and that of the lower sphere horizontally. Once the halves are soldered the seam is polished. Most of the double beads show mechanical damage and discolorations from being worn, but more seriously from being deposited in soil for some two millennia. 7–8 granules separate the upper and lower spheres of a given bead. Granules are more sensitive to production damage such as applying too much heat during soldering. Fig. 5 shows a breach in the solder between the granules. This may have been necessary for air to escape during dramatic changes in temperature, i.e. during soldering.

The spherical gold beads (1–33) (Fig. 1g) are manufactured the same way as the spheres of the double beads. As strung, the seam of all also is vertical. The direction of the perforation in most cases is from the outside toward the inside, but in seven cases the direction was unclear. The seams are polished. There is no difference in the kind of damage, the single and double beds compared with each other. The surfaces show red accretions.

1) Mechanical surface cleaning

Surface deposits were removed with a rotating goat hair brush and plexiglass scrapers. The work was done under the stereomicroscope at 8x magnification. The reddish or blackish layers (surface conditions *b* and *c*) could not be completely removed in this way. Remaining discolourations were left untreated to avoid damaging the soft, thin gold hemispheres.

After cleaning, the well-preserved, smooth gold surface again was visible. The slight reddish or blackish colour of individual beads can be traced back to the other finds which corroded on. The total weight of the beads is 7.627 g (single bead approximately 0.025 g, double bead approximately 0.202 g). Strung, the beads form a chain with a length of 22.5 cm.

2) Stringing the beads on braided nylon string

The number of beads suggests that single and double beads were lined up alternately and that two single beads lying side by side formed the ends. The appearance of the flat single bead cannot be determined. In 1992 the single and double beads were strung together.

3) Bead production

The hollow bead spheres are made of the thinnest possible sheet gold. Each consists of two hemispheres which were swaged separately into a hemispherical die (Fig. 1c).

For bead stringing a sharp instrument pierced the thin wall of the upper bead sphere. The bent edges of the holes show the direction of penetration: it happened inconsistently, partly from the outside in, partly in the other direction. The holes must have been made before the two hemispheres were joined.

At first glance, the larger, lower spheres of the double beads did not seem perforated. However, it turns out that there is a hole here, too (ø 0.18 mm), visible between the subsequently soldered granulations (Fig. 1f). It might have served to prevent the sphere from damaging the seam.

Two hemispheres of each bead sphere were inserted into each other, usually a slightly smaller half inserted into a slightly larger one. Small pinch-folds in the overlap area often formed when fitting one half into the other. In a few cases the edges of hemispheres are broken and fitted together irregularly (Fig. 1e). To judge from the weight, the spheres are hollow.

Solder was applied sparingly to the seam (see below), which penetrated the overlap creating a stable connection. The soldered seam, completely smoothened on individual beads, in most cases is still visible (Fig. 5).

The economical and durable connection of granules and gold ground requires a special technique of soldering, since when using ordinary, metallic solder, the interspaces of beads are filled and the granules would be disarticulated.

One possibility would be to use a reaction solder made of copper salts. The powdered copper salt is mixed with an organic substance (e.g. fish glue) and this paste is diluted with water and applied to the base metal. The granules adhere to the sticky ground. When heated, the fish glue converts to carbon, which reduces the copper salt to metallic copper. When heated to a greater extent, the copper and gold of the base and the granules form an alloy whose melting point is below that of the spheres. This alloy acts as a solder and connects the granules to the base.

The exact sequence of the assembly cannot be clarified. Conceivable would be soldering in two steps, first the granules and then the two spheres together (Fig. 1f). Fig. 5 shows the direction of string-hole perforation, in this case is from the outside toward the inside.

4) Granule production

If one sprinkles finest gold wire or sheet metal chips in a crucible with coal dust and heat it in a melting furnace, the gold particles contract into small spheres at the moment of melting. After cooling, these are washed out in water, dried, sorted by their size and sieved in order to sort uniform grain sizes (Nestler, Formigli 2001: 50–61).

3. Manufacturing technique, REM results

Further questions about the manufacturing technique can be clarified with the help of the reflection electron microscope (REM).

Research question:

1) Analysis of the alloy components of bead spheres, granules and soldered joints by means of the determination of the associated melting temperatures.

2) Investigation of a possible connection between alloy and surface condition of a, b, c.

The following double beads were selected for material analysis:

XXX (surface condition *a* — yellowish) here: "bead 1"

XXIX (surface condition *b* — reddish) here: "bead 2"

XXVIII (surface condition *c* — blackish) here: "bead 3".

The REM analysed the upper spheres, lower spheres, granules and solder connection of three double beads, for a total of 12 measurements. The uncertainty factor of these non-destructive measurements taken on the object surface = 5–10% (relative). The detection limit is 1% absolute content. The analysis values are automatically normed to 100%.

Table 1

Three double beads show the REM alloy averages.
For the bead spheres these values are replicated by microprobe analysis
(Rösch et al. 1997: 770, Tab. 2)

	% Au	% Ag	% Cu
bead 1			
upper sphere	85	12	3
lower sphere	84	14	2
granules	64	23	13
solder	56	29	15
bead 2			
upper sphere	83	15	2
lower sphere	82	15	3
granules	73	22	5
solder	54	31	15
bead 3			
upper sphere	73	23	4
lower sphere	65	31	4
granules	68	27	5
solder	61	31	8

The solder joints contain a higher proportion of Cu. Since when using a reaction solder the solder connection is created by means of a superficial alloy of the base metal with Cu, the Au or Ag content measured here originally comes from the base beads and the granules. Surprisingly, the solder contains an even higher proportion of Ag than the granules themselves. A possible explanation would be that the Ag (melting point 961°C) was more likely to form alloys than the Au (melting point 1063°C) and consequently it could be enriched in the solder joint. This would be in harmony with the composition of the eutectic in the Au-Ag-Cu system, which at a melting point of 780°C consists of almost 75% Cu, 25% Ag and only a low Au content.

The difference in the melting temperatures of beads, granules and solder is about 150°C for beads 1 and 2 (see Fig. 7), whereby the melting point of the granules is closer to that of the solder, but this is due to the copper accumulation during the soldering process can be. For bead 3 the difference is less than 100°C, possibly only 50°C, which should have caused technical problems. A reliable explanation of the overall finding of this total Ag-rich bead is not known. The absolute melting temperatures cannot be derived exactly from the available “rough” measured values, but they are probably between 850°C and 1000°C.

The production of such tiny masterpieces requires the goldsmith to solder the granules in place without raising their temperature to the melting point. This requires skilful local differences in heating.

4. Archaeological comparisons

As strung, the beads are attractive to the modern eye. However, the original appearance may have been much different to judge from two necklaces retrieved in their original sequence of this same period from contemporary graves (Yule 2001 II: Taf. 426.3, 564b). Especially the second of these shows a sequence highly heterogeneous in terms of size, shape and material.

Double beads made of gold are assigned to the Pe50 (today Be50, 'bead50') artefact class: “twin spherical, one sphere larger, gold, silver, colour: gold or silver” (Yule 2001 I: 95, Abb. 5.8.3; 102). In the SPSS generated coding for beads from south-east Arabia double beads are shape no. 513. In total, 166 gold beads came to light in the excavation of the LIA graves at Samad, some soldered granulation rings consisting of up to 12 granules. Others are of the thinnest possible gold foil consisting of a very small amount of gold that they be attractive and affordable. The gold and silver jewellery recovered at Samad in LIA context is truly granulated.

Table 2

166 gold beads and bead caps came to light from Samad LIA contexts. Catalogued in: Yule 2001: 450–473. The sex of the grave owner is determined both by the skeletal evidence and that of the grave good pattern (Yule 2018: 448–455). The owners of these beads were mature females.

DA no.	grave no.	quantity	origin	bead shape	cat. no.	owner
10421	S2607	1	Samad LIA	granulation ring	7.3	adult ♀
10536	S3013	1	EIA?	cylinder, granulation band	1.13	adult ♀
10661	S10683/1	4	Samad LIA	granulation ring	2.3	adult ♀
10661	S10683/1	2	Samad LIA	bead cap	2.4	adult ♀
11285	S10681/2	1	Samad LIA	sphere with granulation	6.1	adult ♀
11285	S10681/2	2	Samad LIA	biconical	6.2	adult ♀
11285	S10681/2	2	Samad LIA	miniature irreg.	6.3	adult ♀
11297	S10718	1	Samad LIA	granulation ring	2.2	adult ♀
11341	S10710	1	Samad LIA	granulation ring	1.1	adult ♀
11298	S10718	85	Samad LIA	miniature irreg.	2.1	adult ♀
12235	S10841	31	Samad LIA	double sphere	10.5	adult ♀
12235	S10841	35	Samad LIA	sphere	10.6	adult ♀

Silver double beads of the same shape came to light during excavation at the site of al-Bustān in gr. Bu6 / burial 3 (Yule 2001 I: 375, II: Taf. 497, Abb. 13.11.12 & 12.4), gr. S3012, DA 10633 (Yule 2001 II: Taf. 327.15). For these, instead of granulation a simple circular band joins the upper and lower spheres. Even more elaborate is a granulated silver earring, gr. S2172-, DA 10366 (Yule 2001 II: Taf. 439, Abb. 10.3), of the same period but in a different manufacturing technique. Its spheres appear to be hollow and cast, to judge from the raw surface and casting seams.

Excavation yielded an agate bead with two granulated gold bands came to light as a surface find at the EIA site ʿUqdat al-Bakrah (Yule 2018: cat. no. 382). Its dating is uncertain, being in secondary/tertiary context.

It is unlikely that the beads from grave S100841 were produced in eastern central Oman since neither metals workshops nor tools have been identified for this period there — the same one in which metal production appears to stop, the *aflāǧ* appear to fall into disuse, and the population decreases in size, to judge from the reduction in the number of sites.

However a mould for coin casting Abiʾel coins came to light at al-Milayḥa of the PIR (Potts 2012: 135). This shows a debased head of Alexander and should date from the later period, like the fort in which it was found, probably as late as 2nd–3rd century CE. Fewer gold objects have survived in contexts of the PIR (Haerinck et al.: in press). The Gent team also excavated a gold spacer bead in an early al-Milayḥa phase tomb (Overlaet et al. 2016: 42, fig. 9 upper right). This fact says as much about the wealth as it does about the intensity of the grave robbing.

Granulation is well documented as early as the 3rd millennium, in the Royal cemetery at Ur or in the 2nd millennium, for example the splendid golden dagger grip of king Tutankhamun (Nestler, Formigli 2001: 12, fig. 4; general source: Wolters 1981). In its brilliance and exactness Etruscan granulation reaches a technical and aesthetic apex (e.g. Nestler, Formigli 2001: 10, fig. 2). However, true granulation also can be imitated by using cheaper and easier methods. Instead of forming the granules separately on a base plate, on charcoal or by dropping them molten into water, they also can be cast or swaged into moulds (summarised in Schwarcz 2010: 214–7).

In south-east Arabia large examples of granulated gold jewellery have come to light at Dibbā (Genchi et al. 2018: 108, fig. 7e–7i) and Sārūq al-Ḥadīd (Weeks et al. 2017: 54, fig. 22), dating not specified. A few of the granules seem to be manufactured separately (SF 29674). To judge from microscopic photos some are possibly manufactured separately (SF 20469, SF 25361, SF 26831, SF 29931. See Dubai 2019: figs. 5–8). Some are cast imitations (SF 26175, SF 25135, SF 26173, SF 26176). None appear to be pressed beaded wire. The authors of *Dubai Municipality. Logo of gold* write that the granulations rings are cast, which is clear at least in the case of their Fig. 6. In terms of technique, these differ from those from Samad. The most elaborate granulated gold jewellery in our region derives from the corridor tombs at Dibbā (Genchi et al. 2018: 108, fig. 7e–7i). A published selection shows a granulated gold earring, granulated tube-shaped beads and a complex granulated wheel-shaped bead. Their dating is under study.

A key early source of gold granulated jewellery is the 1st millennium royal tombs excavated at Nimrud (Hussein 2014). Also numerous are examples from the six 1st century CE tombs excavated at Tillya Tepe in Afghanistan (Schiltz 2010). For the gold beads which form the subject of this note an Iranian origin in the widest sense seems most likely, to judge from excavated examples. These include the tomb of a rich princess at Ǧubaği which dates to the first half of the 6th century BCE (Shishegar 2017: 206, figs. 6–9, 210, figs., 211, figs. showing jewellery disks). Other relevant finds include:

1) bead granulation from Parthian/Sasanian Vešnveh (Stöllner et al. 2004 II: 674, cat. no. 288b),

2) Parthian/early Sasanian Ǧuban, Gilan (Stöllner et al. 2004 II: 741, cat. no. 416),

3) Middle Elamite ring, Susa “Inšušinak depot” (Stöllner et al. 2004 II: 750, cat. no. 435a),

4) Iron Age rings, Marlik (Stöllner et al. 2004 II: 751, cat. no. 435b, c),

5) Iron Age ear-ring, Marlik (Stöllner et al. 2004 II: 754, cat. no. 437),

6) Iron Age circular pendant, Marlik (Stöllner et al. 2004 II: 754, cat. no. 438),

Given the large number of developed examples of gold granulation from central Iran, north-western Iran and northern Afghanistan, this seems the most likely region as an origin for the gold beads from Oman which form the subject of this note.

The owners of the gold beads from the Samad LIA graves are adult females to judge from their skeletal remains or grave good pattern (Yule 2018: 452–455, fig. 12). Gold beads are rank indicators and these women belong to the uppermost social class 'A' of the Samad population scale to judge from the size of the graves and grave good pattern. Given the original wealth of such Samad LIA graves the skeletons are far more likely to be disturbed than those of average income/status. The main problem with such identity studies in Arabia is the fewness of the excavated graves, the rarity of preserved skeletons but more importantly highly variable documentation standards for graves and grave goods.

Acknowledgements

In 1992 this paper originated as a conservation internship report of Franca Michler († 2017) at the Zollern Institut in Bochum (Michler 1992). The beads came to light in the DFG project “Burials of the Late Iron Age in Oman” (1987–1992, seated at the Deutsches Bergbau-Museum, Bochum). Gerd Weisgerber and Paul Yule both raised funds from the DFG, Fritz Thyssen Stiftung and other foundations for the archaeological component. I thank Thilo Rehren (then DBM) for his generous permission to cite his REM material analyses, text, photo and ternary diagram of the melting temperatures of the metals (Rehren 1992). Franca Michler contributed the documentation of the bead technology to further this project. Yule contributed the archaeological comparisons, redrew and edited the images. Years after the fact, thanks go to Joachim Kunkel (†, DBM), for actively coordinating conservation efforts toward my *Habilitationsschrift*. Finally, I am beholden to Christine Pariselle (Paris) who with her expert conservation mastery kindly criticised this paper and made suggestions. My intention was to save the foregoing information, which for years slumbered in my papers, from obscurity.

Bibliography

Dubai 2019 — *Dubai Municipality. Logo of gold*. Dubai, 2019.

Genchi et al. 2018 — Genchi F., Fattore L., Nava A., Maini E. “The LCG2 Complex at Dibbā (Musandam, Oman, II–I Millennium BC): Structural, Material, and Osteological Elements”. *Proceedings of the Seminar for Arabian Studies*, vol. 48, 2018, pp. 99–117.

Haerinck et al. in press — Haerinck E., Overlaet B., De Waele A., Delrue P. *Small Finds from ed-Dur, Umm al-Qaiwain, U.A.E.* (*Late 1st Cent. BCE to Early 2nd Cent. CE*) (*Excavations at ed-Dur IV*). Leuven, in press.

Hussein 2014 — Hussein M. "The Gold of Nimrud". In: Aruz J., Graff A., Rakac Y. *Assyria to Iberia at the Dawn of the Classical Age*. New York, 2014, pp. 125–131.

Michler 1992 — Michler F. *Restaurierungsbericht Objekt*: 66 Perlen, 1992 (unpublished report 5 pages + 6 tables).

al-Moosawi et al. 2016 — al-Moosawi J., Najwani Sh., al-Balushi M., al-Rujaibi S. *The National Museum Sultanate of Oman Highlights*. London, 2016.

Nestler, Formigli 2001 — Nestler G., Formigli E. *Etruskische Granulation*. Siena, 2001.

Overlaet et al. 2016 — Overlaet B., Haerinck E., de Prez B., Pince P., von Goethem L., Monsieur P. "Preliminary Report on the 2014 Belgian Excavations at Mleiha Area AV, Sharjah (UAE)". *Sharjah Archaeology*, 15, 2016, pp. 35–44

Potts 2012 — Potts D. *In the Land of the Emirates the Archaeology and History of the UAE*. London, 2012.

Rehren 1992 — Rehren T. *Technologische Untersuchung mit dem Rasterelektronenmikroskop* (*REM*), 1992, unpublished report (3 pages).

Rösch 1994 — Rösch C. *Präislamische Schmuckperlen aus dem Sultanat Oman — Mineralogisch-materialkundliche Untersuchungen*. Diplomarbeit Inst. für Mineralogie der Universität Würzburg (U. Schüssler), 1994. URL http://archiv.ub.uni-heidelberg.de/propylaeumdok/volltexte/2009/305

Rösch et al. 1997 — Rösch C., Hock R., Schüssler U., Yule P., Hannibal A. "Electron Microprobe Analysis and X-ray Diffraction Methods in Archaeometry: Investigations on Pre-Islamic Beads from the Sultanate of Oman". *European Journal of Mineralogy*, 9, 1997, pp. 763–783.

Schiltz 2010 — Schiltz V. "Tillya Tepe". *Gerettete Schätze Afghanistan Die Sammlung des Nationalmuseums in Kabul, Exhibition catalogue, Kunst- und Ausstellungshalle der Bundesrepublik Deutschland*. Bonn, 2010, S. 152–227.

Schwarcz 2010 — Schwarcz D. "Metalwork of the Early Avar Period: Granulation, Filigree — Imitation". *Tyragetia*, 4,19,1, 2010, pp. 208–223.

Shishegar 2017 — Shishegar A. „Zwei neuelamische Prinzessen und ihre königlichen Bestattungen". *Iran frühe Kulturen zwischen Wasser und Wüste*. Bonn, 2017, S. 202–213.

Stöllner et al. 2004 — Stöllner T., Slotta R., Vatandoust A. (eds). *Persiens antike Pracht, Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum…* 2 vols., Bochum, 2004.

Weeks et al. 2017 — Weeks L., Cable C., Franke K., Newton C., Karacic S., Roberts J., Stepanov I., David-Cuny H., Price D., Bukhash R., Radwan M., Zein H. "Recent Archaeological Research in Saruq al-Hadid, Dubai, U.A.E.". *Arabian Archaeology and Epigraphy*, 28, 2017, pp. 31–60

Wolters 1981 — Wolters J. "The Ancient Craft of Granulation". *Gold bulletin*, 14, 1981, pp. 119–129.

Yule 2001 — Yule P. *Die Gräberfelder in Samad al Shān* (*Sultanat Oman*): *Materialien zu einer Kulturgeschichte*. Rahden/Westfalen, 2001.

Yule 2018 — Yule P. "Toward an Identity of the Samad Period Population (Sultanate of Oman)". *Zeitschrift für Orient-Archäologie*, 11, 2018, S. 438–486.

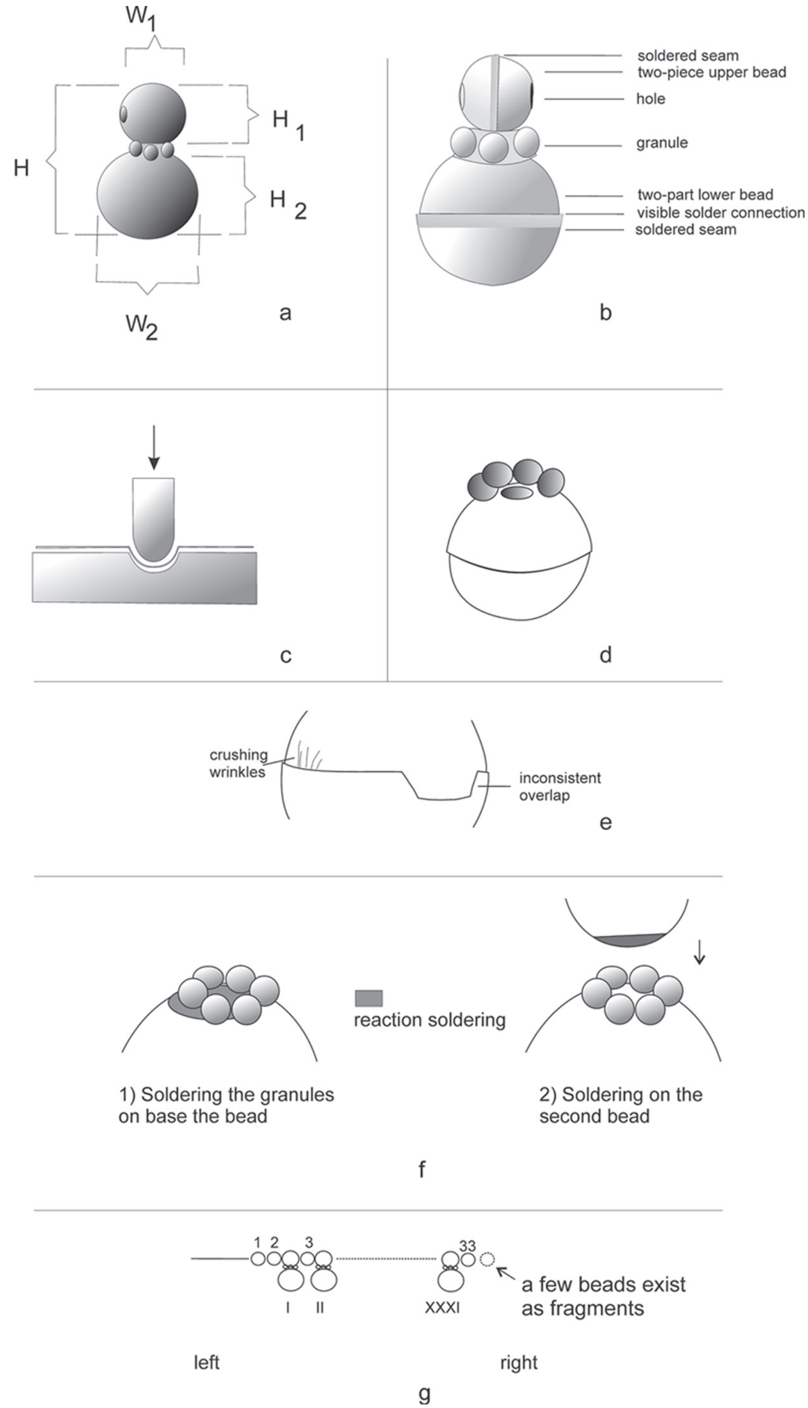

Fig. 1.
a) How measured, b) how assembled, c) manufacture of the bead halves,
d) ventilation hole in lower bead, e) irregular fitting together of the halves,
f) soldering of granules and spheres, g) the numbering of the beads

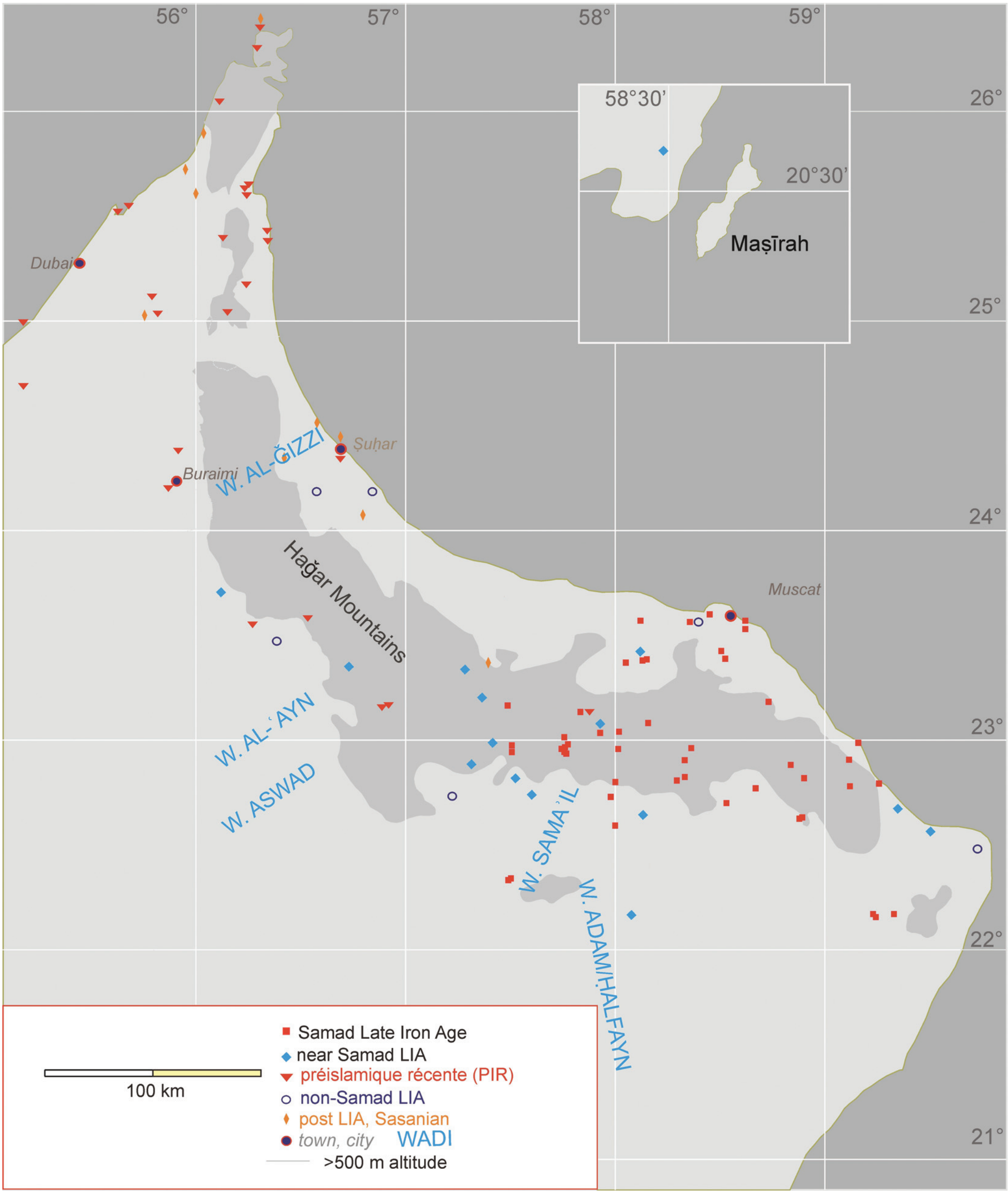

Fig. 2.
LIA archaeological sites in SE Arabia. State: 3.04.2020

Fig. 3.
66 gold beads, selected
from the lot, DA 12235,
which came to light
in the LIA grave, S100841

Fig. 4.
The total of 223 beads of the lot,
DA 12235, to the right, 10 cm

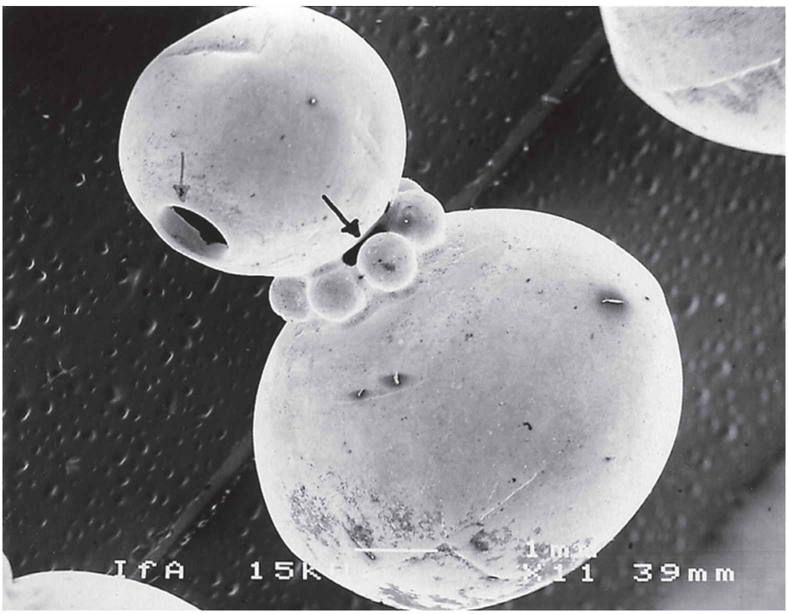

Fig. 5.
REM micrograph shows the soldered seams and granules of a double gold bead.
Grey arrow points to the suspension hole in beads and soldered granules.
Black arrow points to the perforation for the string was punctured from the outside.
The gap between the granules may be intentional

Fig. 6.
The beads came to light scattered on the south-western part of the floor of the Samad LIA grave S100841. The physical anthropologist, M. Kunter, identified the skeletal remains as “tendency female, 20–25 years of age, skeleton badly disturbed, head toward the south-south-east”

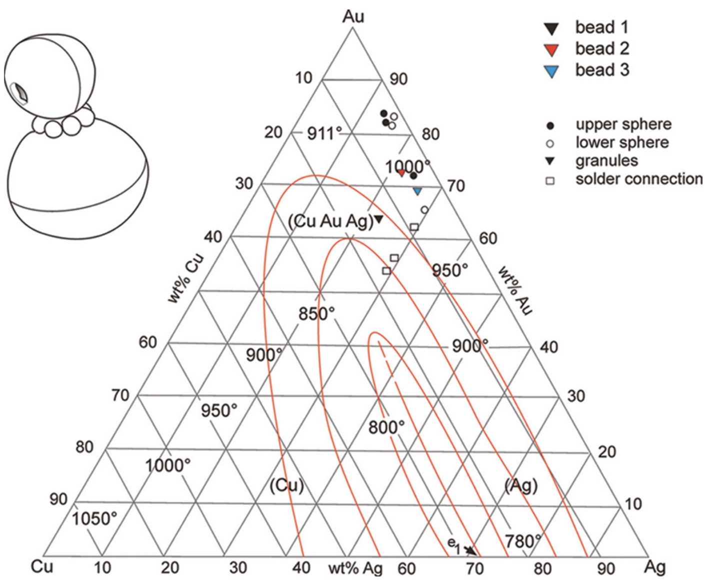

Fig. 7.
This ternary diagram shows the different melting points of the bead bodies, solder and granules