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Iron Age metallurgy at Salūt (Sultanate of Oman): a preliminary note (poster)

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Summary

Extensive excavations at the Iron Age site of Salūt, near Bisyā in central Oman, revealed a complex architecture, allowing the reconstruction of a long history of building activities and rearrangements.

Among the discovered structures, none can clearly be associated to metal production, although a small vertical furnace could be tentatively interpreted as a metallurgical structure, possibly used for small-scale copper/bronze remelting. The presence of charcoal-rich deposits, metal scraps, and stored broken objects in its vicinity also points in this direction. A selection of these items, together with some plano-convex ingots from other contexts within the site, has been analysed and the preliminary results are outlined here.

The significance of this work is underlined by the current dearth of data on Iron Age metallurgy in the Oman peninsula, compared to comprehensive studies of Bronze Age metal production, when the land of Magan was widely renowned for its wealth of copper ores.

Keywords: Iron Age, Salūt, south-east Arabia, archaeometallurgy, copper working

Archaeological setting

The fortified site of Salūt is located in the heart of the Oman peninsula (Fig. 1/a). The site's impressive architecture occupies a small, barren rocky hill dominating the plain north-east of the modern town of Bisyā (Fig. 1/b), not far from the cities of Bahlāʾ and Nizwa (Nizwā) and a few hundred metres east of Wādī Sayfam, a tributary of Wādī Bahlāʾ.

The heyday of the site was during the local Iron Age (*c*.1300–300 BC), with a definite rearrangement during the late phase of the period, starting in *c*.650 BC (Phillips 2010; Phillips, Condoluci & Degli Esposti 2015).

During excavation (2004–2014), several metal objects and pieces of metallurgical waste were collected. This waste can be linked to small-scale copper/bronze working activities, although no firing structures can be safely associated to them. Together with finished objects including weapons and tools, the finds comprise a few fragments of crucibles, rare iron objects, copper-based melting droplets, scrap metal and damaged objects apparently stored for remelting (Fig. 2/a), as well as several plano-convex ingots (Fig. 2/b) from different contexts around the site.

In addition, the discovery of a tap slag fragment raises the question whether primary copper production could have also taken place here, although no other waste related to ore processing has been found so far. Whatever the case, smelting activities could have been carried out outside the walled perimeter, especially considering the toxic nature of associated gases.

No ^{14}C dates are currently available for the precise contexts of the analysed materials. Their Iron Age date is secured, however, by stratigraphy or by typological comparisons in the cases of unsealed contexts. Comparisons have considered similar materials from different sites across south-east Arabia, although not always sufficiently to distinguish between an Early Iron Age and a Late Iron Age date.

Iron Age metallurgy in Arabia

Iron Age metallurgy in south-east Arabia remains a remarkably poorly studied subject, despite extensive studies that addressed Early Bronze Age metal production in 'the copper mountain of Magan' (e.g. Begemann et al. 2010; Hauptmann 1985; Hauptmann, Weisgerber & Bachmann 1988; Weeks 1997; 2003; Weisgerber 1980; 1981). After that date, copper probably continued to be extracted in Oman and this exploitation was still quite substantial during the second millennium BC (Wadi Suq and Late Bronze Age periods). Conversely, what

Figure 1. a. *A map showing the location of Salūt in central Oman (from the Perry-Castañeda Library Map Collection, available at www.lib.utexas.edu/maps/middle_east_and_asia/oman_rel96.jpg);* **b.** *a general view of the Iron Age site of Salūt from the east, after the restoration campaign (early 2015; photograph: Italian Mission To Oman [IMTO]).*

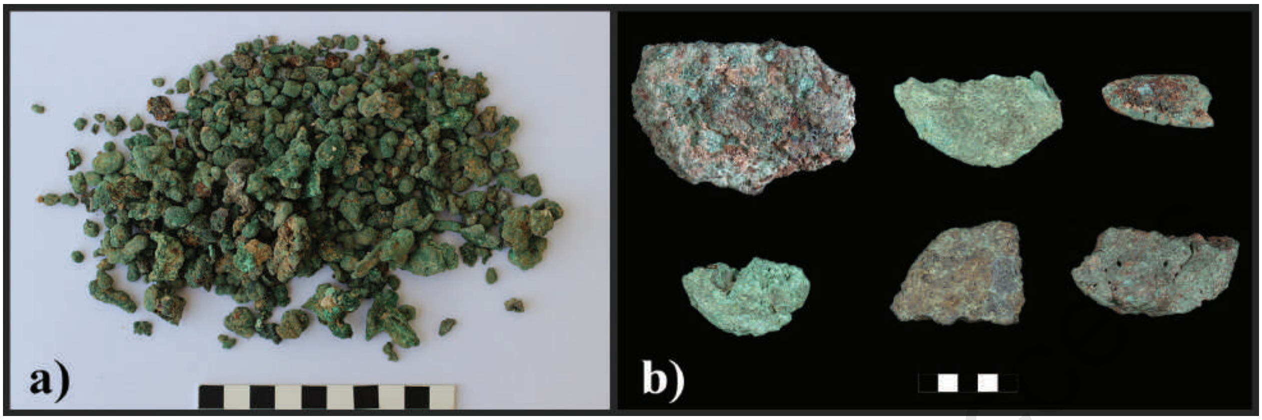

Figure 2. a. *Scrap metal and melting droplets from Salūt;* **b.** *a selection of plano-convex ingots found at Salūt (photographs: M. Renzi).*

happened in the first millennium BC remains rather unclear. It seems that production continued, as indicated by smelting sites such as Raki 2 (al-Rākī in the province of Yanqul; e.g. Weisgerber 2008), but apparently, Magan was no longer linked to long-distance trade (for a discussion of production periods in Oman, see Weeks 2003: 33–43).

Understanding the role and scale of metal production during the Iron Age is one of the main open issues for this region. Also pending is the identification of the technological processes and the main metal alloys used, as well as determining the resources eventually exploited. Despite the very limited amount of production waste found at Salūt, the analysis of this varied set of materials can undoubtedly boost a more in-depth knowledge of Iron Age Arabian metallurgy. Furthermore, the above-mentioned assemblage of plano-convex copper ingots offers a privileged insight into the type of raw material that was circulating in the area.

In this paper, we present preliminary results of the elemental analysis of a group of finished objects and some of these ingots. Most of these samples are securely dated to the Early Iron Age.

Inductively coupled plasma mass spectrometry (ICP-MS) analysis of finished objects

Fifteen finished objects from Salūt were analysed by inductively coupled plasma mass spectrometry (ICP-MS) (Fig. 3). This selection includes nine arrowheads of different size and typology, an axe, a spearhead, a snake head, and other fragmentary items (Fig. 4/a).

The only tin-bronze object is an arrowhead containing 9.7% Sn. The composition of the other arrowheads is predominantly copper, often accompanied by elevated amounts of tin (max. content of 0.6% Sn), arsenic (up to 0.3% As), and nickel (up to 0.8% Ni). In several specimens, the trace elements seem to follow the same pattern. Traces of antimony and cobalt were also detected in most of the arrowheads analysed, including the bronze specimen (Fig. 3).

The composition of the other items is consistent with that of the arrowheads, with two samples showing higher tin contents (1.1% and 2.5% Sn). The presence of other minor elements (Ni, As, Pb, Sb, Co) is also rather homogeneous (Fig. 3). Overall, we interpret the composition to be due to the smelting of polymetallic copper ores (widespread in the Omani region), which could easily explain the variations in the final metal composition (Radivojevic et al. 2013). It is possible, however, that the two outliers were low tin bronzes, possibly resulting from metal recycling operations.

Portable XRF spectrometer (pXRF) characterization of the ingots

A portable XRF spectrometer (pXRF) was used to analyse qualitatively six ingots and a big lump of metal, likely comprising at least four ingots stuck together due to corrosion (MB156). The ingots' original size shows a wide variability with diameters ranging from 6 to 12 cm (Fig. 2/b), similarly to what is known from the study of a hoard of ingots intentionally hidden inside two buried jars at the Iron Age site of Masafi-1 in the

Sample_ID	*Type*	*Cu*	*Fe*	*Sn*	*Ni*	*As*	*Co*	*Ag*	*Sb*	*Pb*	*S*	*SUM*
MB223	Arrowhead	70.85	0.12	**9.79**	**0.25**	0.04	0.02				0.17	81.23
MB88	Arrowhead	86.53	0.07	0.01	0.01	**0.29**	0.02		0.05	0.02	**0.46**	87.38
MB224	Arrowhead	73.78	0.13	0.01	0.07	0.04					0.17	74.26
MB225	Arrowhead	87.87	0.42	0.01	0.02	0.08		0.02	**0.17**		0.21	88.65
MB175	Arrowhead	83.48	0.14	**0.15**	**0.11**	0.08			0.02	0.04	0.09	84.09
MB188	Arrowhead	82.71	0.24	**0.33**	0.06	**0.13**			0.02		0.08	83.57
MB183	Arrowhead	76.10	0.31		**0.77**	**0.26**	0.05				0.15	77.61
MB203	Arrowhead	88.24	0.29		**0.02**	0.04	0.01		0.01	0.01	0.23	88.83
MB178	Arrowhead	70.70	0.08	**0.60**	**0.02**	**0.23**			0.05	0.02	0.22	71.86
MB196	Axe	94.10	0.10	**2.59**	0.06	**0.52**	0.02	0.01	0.05	0.03	**0.37**	97.74
MB199	Blade	76.82	0.14	**1.10**	**0.23**	**0.17**	0.01			0.02	0.26	78.85
MB211	Dagger/Spearhead	91.22	0.05	**0.15**	**0.34**	**0.22**	0.02			0.01	0.14	92.12
MB215	Hoe	91.29	0.08	**0.31**	**0.15**	**0.34**	0.02	0.01	**0.16**	**0.73**	**0.56**	92.74
MB197	Rivet	95.75	0.21	0.03	**0.50**	**0.37**	0.06			0.01	**0.41**	97.27
MB7	Snake head	98.50	0.01	0.01	0.03	**0.18**			0.03		0.02	98.75

Figure 3. *ICP-MS results of the composition of fifteen objects from Salūt (wt %).*

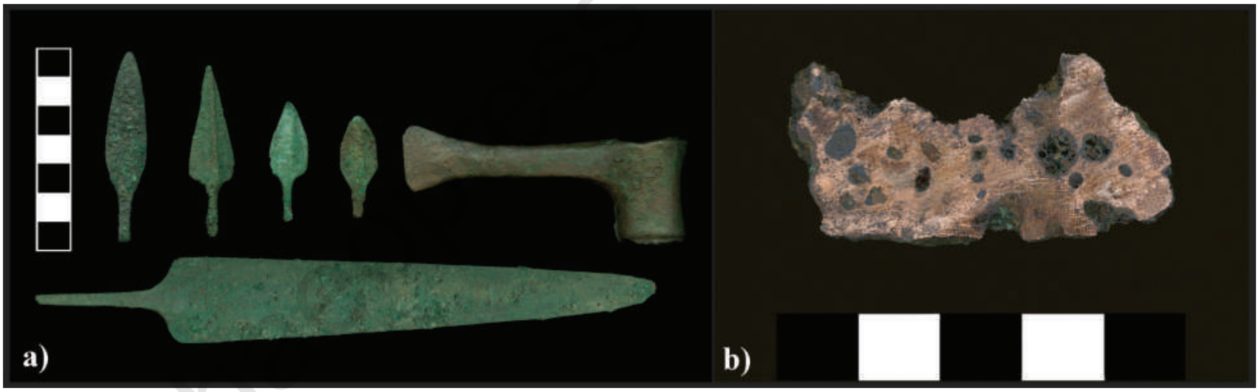

Figure 4. a. *Some of the finished objects from Salūt analysed by ICP-MS;* **b.** *slag inclusions and other impurities visible in the cut section of one plano-convex ingot (MB148) from Salūt (photographs: M. Renzi).*

Emirate of Fujairah, UAE (Goy 2012; Goy et al. 2013). The ingots from Salūt are well preserved and the pXRF measurements were carried out on clean-cut surfaces by analysing multiple spots on the same sample (4–8 spots per sample, according to their size/characteristics).

Although some ingots include slag and other impurities that are visible to the naked eye (Fig. 4/b), the composition of the metal matrix is homogeneous (Fig. 5).

Five of the six ingots are iron-rich, with iron contents of 2.5 to 14% Fe, and around 0.25% of cobalt. The other ingot (MB 150) contains only traces of iron and almost no cobalt, and it is also the only one with some tin (0.3% Sn) (Fig. 5). This might suggest the use of a different source of metal or a different stage of refining. The five Fe-rich ingots also show sulphur contents of up to 2.5%, and arsenic and nickel in the order of up to 1%, while

Sample_ID	Type	Cu	Fe	Co	Ni	As	S	Sn
MB216	Ingot	86.2	9.7	0.2	0.1	1.2	2.1	
MB148	Ingot	83.8	11.7	0.2	2.4	1.2	0.3	
MB147	Ingot	81.8	14.7	0.3	1.7	0.2	0.6	
MB155	Ingot	84.2	11.4	0.3	1.3	0.7	2.6	
MB152	Ingot	94.7	2.5	0.1	0.7	0.5	1.0	
MB150	Ingot	95.9	0.1		0.7	0.3	0.5	0.3
MB156	Lump of ingots	89.6	7.3	0.1	0.5		1.9	

Figure 5. *pXRF results of the main elements detected in the ingots from Salūt (values normalized to 100%; wt %).*

no arsenic was detected in MB156. The presence of these high amounts of iron, sulphur, and slag inclusions indicates that the ingots were made of unrefined metal.

Bearing in mind the different accuracy of the two analytical methods used, which is much lower in the pXRF, the results of Salūt ingots are closely comparable with the group of finished objects that has tin contents below the detection limit (<0.03% Sn).

Conclusions

Despite its preliminary nature, the data presented here allow some interesting considerations. The use of tin-bronze seems so far extremely rare at Salūt during, at least, the Early Iron Age, and this could reflect a more general trend if we look at the available data from coeval sites elsewhere in Arabia (for a similar case see e.g. Renzi et al., this volume). For example, similar figures are reported for a small group of recently analysed objects from the Iron Age sites of Masafi-1 and Masafi-3. Also at these sites, the use of tin bronze seems to be extremely limited (Goy et al. 2013: fig. 9), although among the studied samples only one, a knife, would have received functional advantages from the use of tin bronze. Masafi-1 ingots also provide good parallels for the composition of the ingots from Salūt, as all of them have a remarkable iron content, as well as arsenic, nickel, cobalt, and in one case tin (2.2% Sn; Goy et al. 2013: fig. 9).

The use of tin bronze at Salūt does not seem to be functionally correlated with any class of tools or weapons. The analysed axe, some of the arrowheads, and the small blade from Salūt, items for which the higher strength provided by the addition of tin would have been desirable, are made of a dirty copper with a small amount of tin (from 0.2% to 2.6% Sn), but not in quantities that would consistently affect the properties of the alloy. Moreover, only one out of the nine analysed arrowheads (MB223) was manufactured using a proper tin-bronze. Interestingly, of a large group of arrowheads from the Jabal al-Buḥayṣ necropolis (Sharjah, UAE), those from IA graves are not bronzes but are made of copper accompanied by some tin, nickel, and arsenic (Jasim 2012; Attaelmanan, Yousif & Jasim 2013: table 1).

The question is whether the variable and relatively small amount of tin detected in seven of the samples from Salūt can be considered as impurity of the ores or residual tin from recycling or remelting operations. The presence in practically all these samples of other impurities, such as sulphur, cobalt, arsenic, and nickel, suggests we are not dealing with recycled metal. Therefore, the elemental composition of the two groups of materials, mainly discriminated by the presence or absence of tin and identified in both the finished objects and the ingots, could point to the possible use of two different ore types, one richer in fahlore (a grey or black copper ore) and associated complex minerals (Radivojevic et al. 2013), and the other being cleaner chalcopyrite. Copper circulated as ingots of mostly unrefined metal. These ingots show a great variability in shape and weight, as well as variable amounts of impurities. Their composition is consistent with an origin from the ophiolite-hosted copper sulphide deposits (mainly chalcopyrite), well documented in the Omani region.

The continuation of this work will consider wider parallels in order to test whether this lack of tin bronzes is a local or a more widespread phenomenon. In addition, a broader sampling is needed to draw a better picture of metallurgical techniques and processes carried out at the site (i.e. crucible refining of copper; intentional alloying or melting of scrap metals; possible smelting activities, and so on). The results of ongoing lead isotope analyses will also help to shed light on the possible metal sources and will provide more solid evidence for reconstructing metal exchange patterns in south-east Arabia during the Iron Age.

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