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Early Iron Age metal circulation in the Arabian Peninsula: the oasis of Taymāʾ as part of a dynamic network (poster)

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Summary
The oasis of Taymāʾ, located in north-western Arabia, between the Ḥijāz mountains and the great Nafūd desert, was strategically situated on one of the branches of the main trade routes that connected southern Arabia and the Mediterranean Sea during the first millennium BC.

During archaeological excavations at this site — a project carried out by a Saudi Arabian-German team — an architectural complex of public character dated to the Early Iron Age (eleventh–ninth centuries BC) was investigated in Area O, in the south-western section of the ancient settlement. Among other finds, a significant concentration of luxury goods (i.e. objects made of ivory, wood, bone, and faïence) was discovered there, together with a few iron and several copper-based artefacts.

Of this assemblage, fifty-eight copper-based objects have been analysed by portable X-ray fluorescence (pXRF), while sixteen have undergone trace element and lead isotope analyses. The objects chosen to be analysed included everyday items, such as rivets and fragments of rods, three small metal lumps, and a bracelet. The data on their elemental composition and lead isotope signatures combined to indicate that different metal sources were used, suggesting the existence of a highly dynamic metal trade in the wider region during the Early Iron Age.

Keywords: Taymāʾ, archaeometallurgy, copper, bronze, Early Iron Age

Early Iron Age occupation at Taymāʾ, north-west Arabia

The oasis of Taymāʾ, in modern Saudi Arabia (Hausleiter 2011) is strategically located on one of the branches of a communication network of the Arabian Peninsula, subsequently known as the 'Incense Road', which connected southern Arabia and the Mediterranean Sea (Fig. 1/a). Occupation at this oasis continued over several millennia, the earliest remains of human activity dating back to the fourth millennium BC (Dinies et al., in press; Haibt 2013).

Excavations in Area O at Taymāʾ exposed an Early Iron Age architectural complex that through a series of ^{14}C results can be dated to the eleventh to ninth century BC (Hausleiter 2011: 111–113). The Early Iron Age complex is located in a flat area south-west of Qraya, the presumed centre of the ancient settlement; the latter is characterized by a 120 x 300 m sandstone outcrop several metres higher than its surroundings, including Area O. The complex is well preserved, even if some sections have been destroyed by later activities, including looting pits and graves of the Hellenistic period (Petiti, Intilia & Hausleiter 2014). The complex covers an area of 1300 m^2 (Fig. 1/b). A 2.2 m-thick stone wall, almost square in shape (38 x 35 m), surrounds an inner area of 1000 m^2. The western sector of this complex is occupied by a rectangular edifice, Building O-b1, measuring 23 x 12 m (270 m^2) and several parts of it show traces of fire. A number of other rooms are located to the east and north of it, while the northern and southern corners of the complex are open areas. A cistern, fed by a small underground channel originating outside the complex, is located in the middle of the northern courtyard, while a deep silo was excavated next to the southern corner of the enclosure.

A large number of finds belonging to the original inventories of this complex, especially to Building O-b1, were recovered from its floors and from collapsed debris sealing the floors. In addition to significant quantities of plain and painted pottery vessels belonging to the very distinctive Early Iron Age Ware attested at Taymāʾ (Hausleiter 2014: 414), the excavations produced copper, iron, and gold artefacts. Other items were found in the same building: tokens and combs made of ivory; faïence figurines, vessels, and amulets of probable Egyptian origin (Sperveslage 2013: 240–243); inlays and small engraved bone plaques; and remains of engraved wooden furniture. The exact function of the complex is unclear but its general layout, the typology

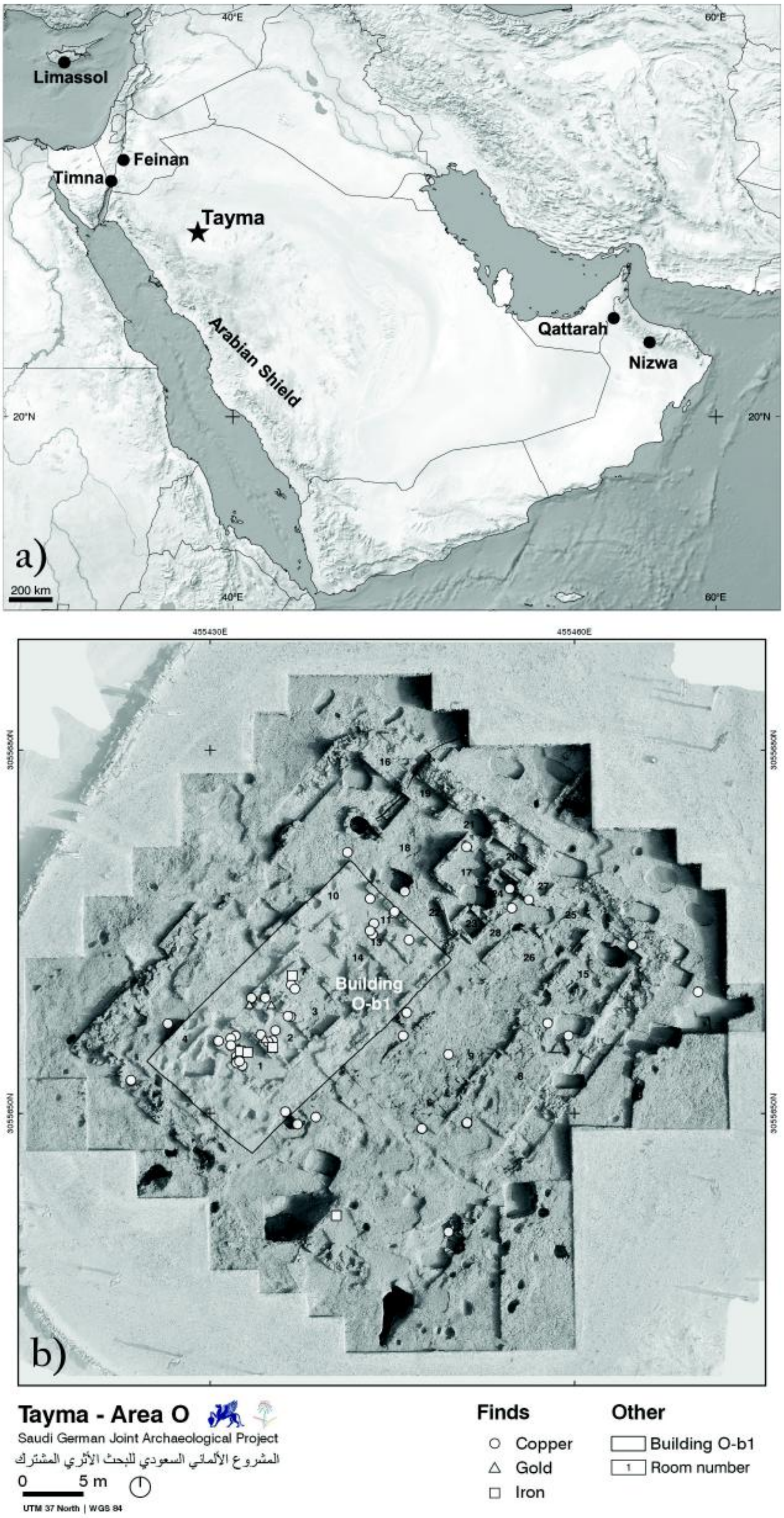

Figure 1. a. *A map of the Arabian Peninsula and Levant showing the sites mentioned in the text (© DAI Orient-Abteilung, S. Lora, made with Natural Earth);* **b.** *a plan of Area O showing the distribution of Early Iron Age metal objects (© DAI Orient-Abteilung, S. Lora).*

of finds, and the fact that the pottery records consist almost exclusively of small and medium-sized open vessels suggest that Building O-b1 was an important structure, most likely public in character and possibly ritual in nature (Hausleiter 2011; Sperveslage 2013).

Metal objects and their composition

More than 120 metal items were recovered from layers located within the Early Iron Age complex in Area O. Seventy-four of the copper-based artefacts were selected for analysis in order to determine the type of alloy used in this period. Unfortunately, most of the analysed objects do not have a recognizable shape due to their small size or to corrosion that distorted the metal. Simple rods, which in most cases have a flattened end, compose the largest group of objects. Some rivets, fragments of sheet metal, amorphous lumps, and melting drops have also been documented, but no clear evidence of metallurgical activities has so far been identified at Taymāʾ for the period under discussion. Two small fragments of possible crucibles from Area O were recovered inside a looting pit. Their date, therefore, cannot be safely established, although no late materials were found associated with them. Some crucible fragments related to bronze alloying activities were found in Area D, in contexts several centuries later than the Area O objects under discussion (Liu et al. 2015).

The first set of analyses was carried out by portable X-ray fluorescence (pXRF) on fifty-eight specimens (Fig. 2), by analysing the cleaned surface. In most cases, however, the objects were fully mineralized and the effect of corrosion has to be taken into consideration when interpreting the results. In fact, surface enrichment in certain elements, such as tin and lead, can occur (Orfanou & Rehren 2015).

Sample_ID	Type	Cu	Fe	Sn	As	Pb	Sb	Co	Ni	S	Zn	Ag
TA12509	Band	72.3	**2.8**			**0.9**					**0.3**	
TA4506	Lump	55.6	**2.7**							**5.8**		
TA9413	Lump	82.9	0.6			0.5				0.3		
TA16218	Lump	90.7	0.8							**1.3**		
TA5820	Lump	84.6	0.3			0.1				**1.8**		
TA5280	Lump	78.4	**14.4**	**1.1**	**5.3**	0.1			0.2			
TA14720	Lump	72.3	**2.4**			**1.4**					**1.5**	
TA10533	Lump	86.2	0.6			**0.9**						
TA15285	Lump	74.3	0.4	**1.6**	0.2	0.2				0.8		
TA7904	Melting drop	81.9	**1.0**							0.4		
TA16212	Melting drop	69.9	**2.7**							0.5		
TA16219	Melting drop	75.9	**2.2**	0.7	0.1	0.2				0.8		
TA16213	Melting drop	84.3	0.2							0.5		
TA15780	Melting drop	78.0	**4.7**		**1.3**		0.1			0.5		
TA5623	Melting drop	67.1	**2.1**		**4.2**	0.1				0.7		
TA16220	Melting drop	71.0	0.5		**6.2**	0.2			0.1	0.9	0.1	
TA16216	Melting drop	79.4	**1.5**	**1.9**	0.5	0.1				0.3		
TA16215	Melting drop	74.4	**3.7**	**1.3**	**1.2**	0.1	**0.6**	0.1		0.4		
TA5938	Melting drop	88.5	0.3							0.5		
TA9428	Melting drop	77.4	0.5							0.5		
TA5266	Melting drop	69.7	0.6							**1.5**		
TA4612	Melting drop	67.4	**2.3**		**2.5**	0.1				0.6		

Sample_ID	Type	Cu	Fe	Sn	As	Pb	Sb	Co	Ni	S	Zn	Ag
TA15798	Plaque	89.1	**1.0**	0.1	**4.3**	0.5	0.1			0.4		
TA16211	Rivet	91.4	0.4			**0.9**						
TA16207	Rivet	82.5	0.5			0.5				0.5		
TA9425	Rod with flat end	89.9	0.3	0.1		0.4				0.3		**0.7**
TA5636	Rod with flat end	88.4	0.2	0.1		0.3				0.1		
TA5368	Rod with flat end	79.8	0.6	0.1		0.3				0.3		
TA7691	Rod with flat end	87.6	0.3			**1.7**						
TA7543	Rod with flat end	98.5	0.3			**1.2**						
TA12516	Rod with flat end	79.7	0.3			**1.1**						
TA7692	Rod with flat end	86.4	0.3			**1.0**			0.1			
TA7546	Rod with flat end	78.7	0.4			**1.2**						
TA7693	Rod with flat end	73.5	0.4			**0.9**						
TA13059	Rod with flat end	68.3	0.5			**1.3**						
TA7698	Rod with flat end	72.4	0.5			**1.9**						
TA4509	Rod with flat end	69.0	0.8			**1.0**						
TA9619	Rod with flat end	76.8	0.2			0.6				0.4		
TA12506	Rod with flat end	75.3	0.3	0.1		**2.2**						
TA12505	Rod with flat end	79.8	0.3	0.2		**1.0**						
TA5924	Rod with flat end	81.3	0.3	0.4		**0.9**						
TA16209	Rod with flat end	76.3	0.2	0.2		0.6				0.5		
TA7542	Rod with flat end	88.1	0.3	0.5		**1.7**						
TA7542	Rod with flat end	82.9	0.2	0.6		**1.2**						
TA7542	Rod with flat end	81.6	0.2	0.6		**1.2**						
TA7695	Rod with flat end	75.0	0.3	0.7		**1.0**						
TA16208	Rod with flat end	72.3	0.2	0.8		**1.3**						
TA7679	Rod with flat end	73.6	0.4	0.1		**1.1**						
TA7697	Rod with flat end	76.3	0.2	**1.0**		**1.3**						
TA7696	Rod with flat end	57.4	0.3	**1.6**		0.6						
TA16061	Sheet	92.6	0.2	0.2	**3.1**							
TA7694	Sheet	78.2	**1.0**			**1.7**						
TA7689	Sheet	72.5	**1.2**			**1.1**						
TA15897	Unknown object	66.5	0.7							**2.6**		
TA15270	Unknown object	92.5	0.4	**2.3**	0.4	0.1				0.3		
TA16210	Unknown object	76.0	**5.6**	0.2		**1.1**						
TA7658	Unknown object	80.0	0.2			1.0						
TA10657	Unknown object	83.4	0.3	**2.5**	0.3	0.3				0.3		

Figure 2. *pXRF results of the main elements detected in fifty-eight metal items from Taymāʾ (values normalized to 100%; reported in wt %).*

A further sixteen items were analysed by inductively coupled plasma mass spectrometry (ICP-MS) to identify trace elements (Fig. 3), and by lead isotope analyses in order to shed some light on the potential origin of the metal used at Early Iron Age Taymāʾ (Fig. 4). Further ICP-MP and lead isotope analyses on more samples are in progress.

The compositional variability of the whole assemblage is relatively high but two main groups can be identified, despite the analytical uncertainty in the pXRF data (Fig. 2).

Objects of the first group are made of copper, which also contains some lead and/or tin, while the second group shows appreciable arsenic and tin contents, with iron, lead, cobalt, and nickel as the most common impurities. Interestingly, none of the analysed items can be considered proper tin-bronze alloy, as the tin content is too low (always <2.5% Sn) to change noticeably the properties of the metal. ICP-MP analyses on the smaller set of samples also confirm this almost total lack of tin bronzes, with tin contents being typically lower than 3%; the only exception is a bracelet, which shows 5.8% Sn (Fig. 3).

The lack of proper tin bronzes and the small amounts of tin detected in most of the samples raise the question of the origin of this tin. It might be either residual from several recycling or remelting operations of bronze scrap as a result of unintentional fire refining (Hofmann & Klein 1966) or an impurity present in the original copper ore (Radivojevic et al. 2013). In some cases, the presence of noticeable amounts of arsenic (in some samples up to 2% As) suggests that we are not dealing with recycled metal, as arsenic is highly volatile in oxidizing conditions. The homogeneous pattern of trace elements within the two identified groups also supports this hypothesis, as multiple recycling events involving tin bronzes would probably have resulted in overall lower and less homogeneous trace-element signatures. Furthermore, recent studies of some smelting slag from the site of Bayt Bin ʿĀtī in the Qaṭṭārah oasis (al-ʿAyn, UAE) provide interesting data that confirm the exploitation, during the Iron Age, of tin- and arsenic-rich copper resources (Rehren et al. 2014). Scanning electron microscopy with X-ray microanalysis (SEM-EDS) analyses of some of the smelting slags collected at that site show the presence of copper prills containing up to 6% Sn and 2% As. Further SEM-EDS, ICP-MS, and lead isotope analyses of these materials are currently ongoing.

Sample_ID	Type	Cu	Fe	Sn	As	Pb	S	Ag	Sb	Co	Ni	SUM
TA 9617	Bracelet	73.50	0.17	**5.85**	**0.14**	**0.61**	**0.18**	**0.12**	0.02		0.07	80.3
TA 5280	Lump	43.28	**11.87**	**0.17**	**1.29**	0.02	**0.45**		0.01		0.03	56.6
TA 8901	Lump	68.66	0.03	**1.11**	**0.10**	0.12	**0.24**					70.0
TA 9845	Lump	67.61	0.12	**2.97**	**0.90**	**0.32**	0.08				0.03	71.9
TA 16061	Metal sheet	88.95	0.14	**0.29**	**2.25**	0.02	0.01	0.02	0.03			91.7
TA 15269	Rivet	60.44	0.41	0.08	0.08	**0.78**	**0.12**			0.01	0.03	61.8
TA 7051	Rivet	49.37	0.16		0.01	**0.60**	0.08				0.01	50.1
TA 15268	Rod	89.79	0.03		**2.06**	0.02	0.02	0.04			0.06	91.9
TA 16059	Rod	63.63	0.15	**1.91**	0.07	0.01	0.08		0.01		0.01	65.8
TA 5841	Rod	30.14	0.35	0.01	0.02	**0.21**	**0.33**					30.7
TA 4609	Rod	68.30	0.23	0.01	0.04	**1.03**	0.06			0.01	0.03	69.6
TA 10684	Rod with flat end	66.04	0.06	**0.63**	0.02	**0.71**	0.02				0.02	67.5
TA 10735	Rod with flat end	57.30	0.16	0.05	0.01	0.13	**0.10**	0.01				57.6
TA 16051	Rod with flat end	74.85	0.17	0.01	0.01	**0.34**	0.04				0.01	75.4
TA 9445	Rod with flat end	65.27	0.35	0.02	0.03	**0.53**	0.09			0.01	0.03	66.2
TA 10683	Unknown object	44.21	0.48	**1.67**	0.01	**0.55**	0.06				0.01	46.9

FIGURE 3. *ICP-MS results of the composition of sixteen metal objects from Taymāʾ (reported in wt %).*

The provenance of the metal

The data pool (Fig. 4) is still too limited to reach firm conclusions on the provenance of the metal used at Taymāʾ during the Early Iron Age, but it already suggests the possible existence of dynamic networks of metal trade and supply.

While the isotope signatures of some samples do not match the available lead isotope data of any specific region, some preliminary observations can be made for a number of other objects. None of them has an isotopic signature that is consistent with the ores from the Arabian Shield (Stacey et al. 1980; Ellam, Hawkesworth & McDermott 1990), although it should be noted that from this large area only galena has so far been characterized isotopically, but no copper ore. The rods, rivets, and an undetermined object — the first group mentioned above — form a very tight isotopic field matching their consistency from the compositional point of view (Cu with Pb and/or Sn). Three items of the second compositional group, characterized by higher tin and arsenic contents form a second cluster with more radiogenic lead (Fig. 5).

Unfortunately, there are several possible origins for both groups due to the partial overlapping of isotopic fields of the copper ore deposits more consistent with our samples. For the first group, the source of metal could be either Timnaᶜ-Faynān in the Arabah (Wādī ᶜArabah) region (Hauptmann et al. 1992; Weisgerber 2006; Hauptmann 2007) or Oman (Calvez & Lescuyer 1991; Begemann et al. 2010), the former being the more likely candidate on geographical grounds. In addition, the archaeological artefacts from Area O indicate that there were cultural contacts between northern Arabia, Egypt, and the Levant at this time.

The isotopic values of artefacts of the second group match those of copper ores from Oman as well as from Limassol in Cyprus (Stos-Gale, Maliotis & Gale 1998) (Fig. 5). Although the idea of long-distance trade of Cypriot copper into the Iron Age is tempting, the results of still ongoing and unpublished lead isotope analyses of smelting slag and metal items from contemporary sites in the United Arab Emirates and Oman support the hypothesis of Omani ores as a more likely source. In fact, it is interesting to note how the isotopic data that best match the samples from Taymāʾ (Cu with As and/or Sn) are the ones from the Raki (al-Rākī in the province of Yanqul) area in Oman (Calvez & Lescuyer 1991), where an important Early Iron Age smelting site is documented

Sample_ID	Type	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{206}Pb$	$^{208}Pb/^{206}Pb$
TA9617	Bracelet	18.0571	15.6546	38.1717	0.8669	2.1139
TA8901	Lump	18.5019	15.6587	38.5537	0.8463	2.0838
TA9845	Lump	18.0179	15.6425	38.1738	0.8681	2.1187
TA5280	Lump	17.9600	15.5600	37.7818	0.8663	2.1036
TA16061	Metal sheet	18.5890	15.6483	38.6586	0.8418	2.0797
TA7051	Rivet	17.9644	15.6350	38.1058	0.8703	2.1211
TA15269	Rivet	17.9752	15.6364	38.1125	0.8699	2.1203
TA5841	Rod	17.9635	15.6386	38.1156	0.8706	2.1217
TA15268	Rod	17.9189	15.6152	37.9785	0.8714	2.1195
TA16059	Rod	18.5249	15.6403	38.6040	0.8443	2.0839
TA4609	Rod	17.9580	15.6336	38.0938	0.8706	2.1213
TA10735	Rod with flat end	17.9677	15.6359	38.1050	0.8702	2.1209
TA10684	Rod with flat end	17.9622	15.6324	38.0990	0.8702	2.1209
TA9445	Rod with flat end	17.9582	15.6332	38.0949	0.8706	2.1213
TA16051	Rod with flat end	17.9682	15.6347	38.1073	0.8701	2.1206
TA10683	Unknown object	17.9523	15.6324	38.0864	0.8708	2.1215

Figure 4. *Lead isotope data of the metal objects from Taymāʾ.*

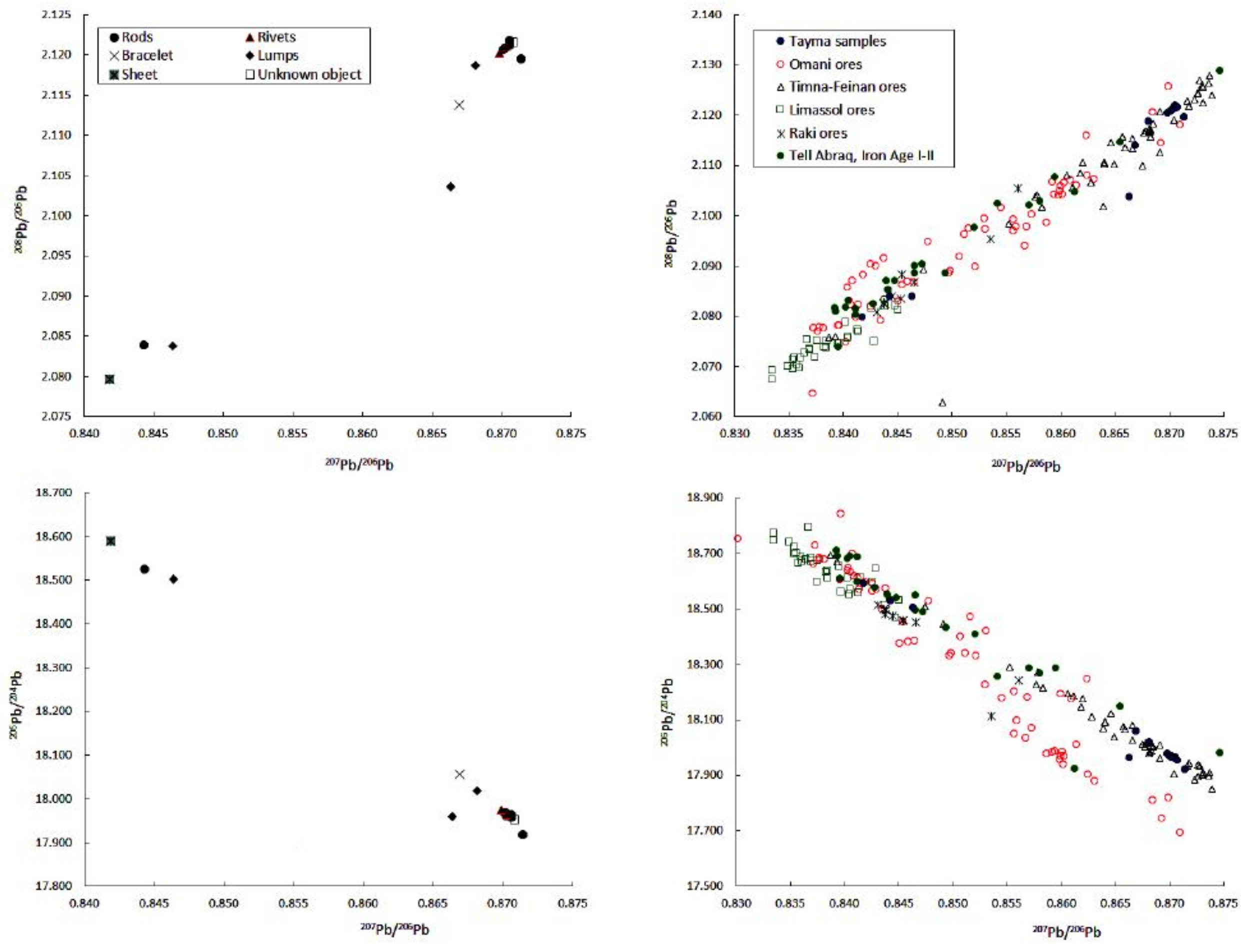

Figure 5. *Diagrams of the ratios $^{207}Pb/^{206}Pb$ versus $^{208}Pb/^{206}Pb$ and $^{207}Pb/^{206}Pb$ versus $^{206}Pb/^{204}Pb$ of the Early Iron Age metal items from Taymāʾ and their comparison with copper ores from Oman, Timnaʿ-Faynān, and Limassol (standard error smaller than the symbol size; © UCL Qatar, M. Renzi & Th. Rehren).*

(Weisgerber 2008). Only a broader sampling for lead isotope analyses combined with an in-depth study of trace elements will help to clarify this question.

Conclusions

The study of the metals from Area O provides interesting data on a still under-studied topic. In particular, published data on metal production in the Arabian Peninsula at the beginning of the first millennium BC are very scarce at present.

The most remarkable result obtained thus far is the lack or, at least, the only very limited presence of tin bronze at Early Iron Age Taymāʾ. In contrast, the arsenic content in several samples is high enough to suggest the use of arsenical copper. Nevertheless, if we consider the frequent association of tin and arsenic in most of the materials analysed, as well as the recent study of Qaṭṭārah smelting slags, an intentional use of resources that provided a natural Cu-As-Sn alloy could be tentatively proposed. Particularly interesting is to see how this natural alloy had an Arabia-wide distribution, confirming the role of the oases as important nodes in trade networks and the still active copper exploitation of the Omani ophiolite mountain range during the Early Iron Age. Nevertheless, the very limited presence of tin bronzes in this period remains surprising, especially if we bear in mind the contacts between north-west Arabia and other parts of the Near East, where tin bronzes were the dominant Late Bronze Age alloy, from Mesopotamia to

Egypt. This connection is also documented by the isotopic composition of the first group of objects (Cu with Pb and/or Sn), possibly from the Timnaᶜ-Faynān area.

A wider and more in-depth study of metallurgical materials from Taymāʾ and other contemporary sites in the Arabian Peninsula is needed to gain a better understanding of metal production systems and trade during this period. From the data emerging so far, however, the north-western Arabian oases seem to have maintained their fairly autonomous role in obtaining raw materials for metal production from different locations, namely, the eastern Mediterranean and the Arabian Peninsula. This was already suggested for the Late Bronze Age (Liu et al. 2015) and it seems to continue into the Early Iron Age, and possibly beyond, as suggested by the site of Qaṭṭārah (see Rehren et al. 2014).

The data obtained thus far, therefore, might reflect an intentional choice of ores possibly connected to a regional metallurgical tradition. A coping strategy was possibly used to overcome potential difficulties in obtaining tin due to the major political and economic changes that occurred in the ancient Near East between the end of the Late Bronze and the Iron Age. At the oasis of Taymāʾ, from the archaeological point of view, the situation is not yet entirely clear and more data are needed on this topic. It seems, however, that at least the strategies of north-western Arabian oases for obtaining copper remained unchanged compared to the Late Bronze Age (Liu et al. 2015). It is not until the mid-sixth century BC, that economic changes with wide-ranging effects may have taken place in Arabian oasis settlements, allowing the Neo-Babylonian king Nabonidus, rather than the earlier Neo-Assyrian empire, temporarily to gain control over some of the most powerful oases in the Ḥijāz (cf. Hausleiter 2012).

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