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Some Reflections on the Ancient Metallurgy of Sumhuram (Sultanate of Oman)

Michele Degli Esposti
CNRS-UMR 6566 CReAAH, Université de Rennes, France
michele.degliesposti@gmail.com

Alexia Pavan
Office of the Adviser to His Majesty the Sultan for Cultural Affairs, Muscat-Salalah, Sultanate of Oman
alepavan@yahoo.com

Abstract

Multidisciplinary research on the metallurgy-related items and features from the ancient South Arabian harbour of Sumhuram, in southern Oman, have shed light on ancient copper and iron production and use at the site, pointing out what appears to be a definitely unusual practice in particular for what concerns copper alloying. In this paper, the archaeometallurgical data are summarised and discussed with the aim of showing that the existence of a copper working tradition specific to South Arabian centres can be tentatively postulated and that at least two different networks of metal production and exchange probably existed, centred on the opposite sides of the southern Arabian Peninsula.

Keywords

bronze – ancient metallurgy – Sultanate of Oman – Sumhuram – Red Sea trade

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Introduction[1]

The extensive excavation of the South Arabian (SA)[2] harbour of Sumhuram provided abundant evidence of productive activities *in situ*, among which bronze and iron working played a significant role. Started in 2007, a comprehensive program of archaeometallurgical research was carried out on the materials collected at the site, the detailed results of which were published for what concerns iron working (Chiarantini, Benvenuti 2011), coin circulation and production (Chiarantini, Benvenuti 2014), copper working (Degli Esposti *et al.* 2018), and the production of inscribed plaques (Chiavari *et al.* 2011). Here, the results of the study on ancient copper working at the site will be further discussed. In fact, the analysed samples display a general inaccuracy of the metallurgical practices and high lead content, inconsistent with any practical advantage. This picture apparently remains unaltered throughout the city's life.

So far, the ancient metallurgy of the southwestern Arabian Peninsula has been neglected in the literature. The only fitting parallel for Sumhuram's dataset was found in the results of analyses carried out in the 1960s on items collected at Hajar Ibn Ḥumayd (HIH), another, partly coeval, key SA site. This admittedly limited evidence might indicate that a specific metallurgical tradition existed, that was shared by SA centres, regardless of contacts with other centres in the Arabian Peninsula. Where can the roots of this tradition be sought after? Some sparse data suggest that the strong connection between the opposite sides of the Red Sea, evident as early as the 5th millennium BC, could play some part in this process. The available evidence is discussed here with the aim of putting forward a preliminary working hypothesis, hoping that this will stimulate new archaeometallurgical studies on SA and Ethiopian artefacts, the latter being currently more feasible given the difficult political situation in Yemen.

1 This paper is the outcome of a cooperative work of the authors. However, M. Degli Esposti more specifically dealt with sections 2 and 3, and A. Pavan with section 1. Financial support for this work came from the Italian Mission to Oman—Dip. di Civiltà e Forme del Sapere, University of Pisa and from the Office of the Adviser to HM the Sultan for Cultural Affairs. The director of IMTO, Prof. Alessandra Avanzini (University of Pisa) is acknowledged for her contribution to the discussion.

2 South Arabia is here intended both in the general geographic sense, indicating the south western part of the Arabian Peninsula, and in the cultural one, that is, belonging to the classical SA kingdoms.

1 The Archaeological Context

1.1 *The Harbour of Sumhuram*

The ancient SA town of Sumhuram, founded in the 2nd cent BC as the easternmost outpost of the kingdom of Ḥaḍramawt, lies on a rocky hill which dominates the estuary of wādī Darbāt, along the Indian Ocean coast, in southern Oman (Fig. 1a,b). Th. Bent (1895) first suggested the correlation of the site with the ancient toponym of Moscha *limén*, one of the southern Arabian coast's harbours mentioned in the *Periplus Maris Erythraei* (Casson 1989). The location of the site, nestled into a small bay embraced by two rocky promontories, makes it a perfectly protected harbour and endowed it with a pivotal role in the global network which connected the Mediterranean Sea to India through the Red Sea and the Indian Ocean. Sumhuram first entered the modern archaeological record in the 1950s, when the American Foundation for the Study of Man (AFSM) carried out investigations which brought to light limited portions of the city (Cleveland 1960; Albright 1982). Since 1996, the extensive work of the team of the Italian Mission to Oman (IMTO), has led to a fundamental improvement in the understanding of the general chronology and layout of the city, and its role in the international trade.

The city was completely walled, with an impressive gate complex opening north (Fig. 1b,c). Inner streets and alleyways defined blocks, for some of which

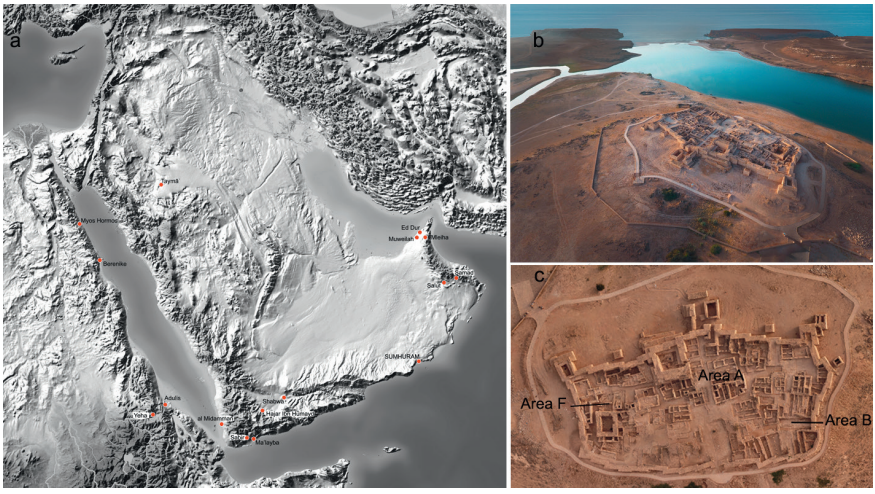

FIGURE 1A–C a) the main sites mentioned in the text; b) panoramic view of Sumhuram, looking southwest; c) zenithal view of Sumhuram with indication of the main Areas
PHOTOS B) AND C) S. BIZZARRI

the functional destination has been generally identified, as is the case of the storage quarter (Sedov 2008*a*) or the residential one (Buffa, Sedov 2008).

No area was specifically destined for production, but evidence for diverse, small scale activities was discovered in different parts of the city. These include metalworking, but also kilns for pottery and lime production. Two religious buildings were so far identified *intra-muros*: the large temple dedicated to the god Sīn (Sedov 2008*b*), and a smaller shrine whose dedication is unknown (Pavan, Degli Esposti 2016). An *extra-muros* cultic building was discovered northwest of the city, close to the wādī bank (Pavan, Sedov 2008).

Water supply within the city walls was only granted by a well cut through the hill's rock and hosted inside the so-called "Monumental Building 1". Water drew from there was conveyed by a channel passing through the massive curtain wall to a series of basins located outside the town. These could provide water for visitors and their pack animals, a hypothetic scenario which strongly underlines the role of Sumhuram in the regional trade connecting the coast with inland sites.

A number of relevant reasons underlie the foundation of Sumhuram some 800 km away from Shabwa, the capital of the Ḥaḍrami kingdom: the proximity to the area where the best quality frankincense (*Boswellia sacra* Flueck) naturally grows, i.e. the Nejd region; the safe harbouring the bay could offer to the ships involved in the long-distance trade that linked the Mediterranean to India, of which frankincense was a key element; and the presence of numerous springs granting an abundant water supply.

Consistently with such a favourable location, materials from all the regions involved in the Indian Ocean global network were found at Sumhuram (Pavan 2011, 2017). The recent discovery of a complete inscribed bronze plaque (KR 11, Fig. 2d) dedicated by the viceroy of Sumhuram and mentioning the bronze he "brought with him (from Sumhuram)" (Avanzini 2014) might suggest the city played a significant role in the trade and distribution of copper-alloys and raw materials, besides the well-known trade of frankincense and other different *aromata*.

At the time of the AFSM investigations, it was believed that Sumhuram found its *raison d'être* in the expansion of Roman commercial activity following the Roman conquest of Egypt in 30 BC (Albright 1982). Recently collected evidence, however, convincingly supports a new date for the city foundation in the early 2nd century BC (Avanzini, Sedov 2005).

The city abandonment is currently dated to the late 4th/5th century AD, with a possible late phase of ephemeral occupation dated to the Late Antiquity and the Early Islamic period. The town's decline was probably gradual, several factors concurring to it. One was the defeat of the kingdom of Ḥaḍramawt by

the Ḥimyarites in the 3rd cent AD, which likely deprived Sumhuram of the strategic importance it had under the former rulers. Sumhuram, however, adapted to the new scenario and established solid links with the new rulers, finally surrendering to the gradual sanding up of the lagoon, today completely separated from the sea by a sand belt (Horn, Cremaschi 2004).

An internal phasing for the site was put forward on a stratigraphic basis. For Area A and F, where more extensive work had been carried out, five constructional phases were defined (Buffa, Sedov 2008; Sedov 2008*b*). This phasing was followed for the archaeometallurgical study,[3] although the recent revision of the data from the whole site and the excavation of the urban shrine allowed the excavators to preferentially define two main occupational macro-phases, plus a later decline one (Pavan, Degli Esposti 2016).

1.2 *Archaeological Evidence for Metal Production and Use at Sumhuram*

Metallurgical installations were discovered in different places. In Area F, a furnace for melting, made from a large storage vessel equipped with the neck of an amphora serving as a tuyère (Fig. 2a), and another clay furnace with tuyère, were unearthed. In the same area, a number of pits interpreted as kilns for iron smelting with some resized stone vessels tentatively interpreted as "tuyère plates" were recently discovered. In Area A, a possible blacksmith workshop was hosted in one of the premises of building BA2 (Buffa, Sedov 2008). In Area B, several simple furnaces for ironworking were unearthed, partially dug into the floors and framed by rough stones (Fig. 2b; Chiarantini, Benvenuti 2011) as well as a possible furnace for the production of clay moulds destined to the manufacture of inscribed plaques. Small scale copper working is also indicated by almost 100 fragmentary and complete small crucibles from different contexts. They were used for melting different copper-base alloys, varying in composition from Cu-Sn to the most frequently attested ternary system Cu-Sn-Pb (Chiarantini, Benvenuti 2011). The recent discovery of a stone mould (S1673, Fig. 2e) for the production of squared-section rods is of interest, as its dimensions are consistent with the crucibles' average capacity, ranging between 4 to 10 cm^3 (Chiarantini, Benvenuti 2014). This association represents indisputable evidence for the local production of metal tools. Less mundane objects were also manufactured at the site, as shown by the discovery of a few fragments belonging to clay moulds (Fig. 2c) which were used to cast inscribed plates or single letters which could be later welded to a plain plaque (Chiavari *et al.* 2011). The abundance of the numismatic finds (Sedov 2008*c*), and specifically the presence of 1259 blanks discovered by AFSM, prompted the suggestion of

3 Periods I–V in Degli Esposti *et al.* 2018.

the existence of a mint in the town (Albright 1982). Analytical data are, however, not sufficient to reach a definitive conclusion about this issue (Chiarantini, Benvenuti 2014).

Ironworking slag is the most widely represented metallurgy-related material found at the site (more than 70 kg). It comprises two different typologies of slag, one richer in silicates and one mainly made up of weathered iron oxyhydroxides; they were interpreted as a by-product of smiting activities, but the rare occurrence of some copper impedes to rule out processes related to its production (Chiarantini, Benvenuti 2011).

No evidence can be connected with copper smelting, thus indicating that the site received raw metal and not ores and that local processing probably mainly used recycled material. This practice is confirmed by the very recent excavation of a pit in room A292 (Area A) filled by loose loam covering a number of bronze objects, coins, and iron scraps, stored to be re-melted for the production of new objects.

Finally, metallic objects were recovered in remarkable numbers at the site (Pavan 2008). They range from cultic offerings (such as inscribed vessels or inscribed plaques of different size) to personal adornments, cosmetic instruments, and everyday use tools, these latter mainly made of iron.

2 An Outline of Ancient Copper Working at Sumhuram

The study of a sample of the copper-base items from Sumhuram provided results which stimulate further discussion about the practices witnessed at the site and how they can correlate with the broader archaeological context of the city. As a full presentation of these data has been recently published,[4] and several technological details go beyond the scope of this paper, they will be only shortly summarised here.

The most evident characteristic is the high and quite ubiquitous Pb content. Almost all the objects can, in fact, be defined as leaded bronzes, with just three exceptions. The Pb content, useful for casting because it improves the fluidity of the molten metal (ASMH 2008), remarkably ranges from 1.1 to 28.8 wt%, clearly indicating a deliberate addition: lead was probably also used to increase the mass of processed metal in the place of other, less readily available and more expensive metals (i.e., tin).

4 All data on Sumhuram's items summarised in this paragraph are from Degli Esposti *et al.* 2018.

FIGURE 2A–E Evidence for metal production at Sumhuram: a) vessel-furnace from Area F; b) ironworking furnace from Area B; c) clay mould Cl50 for bronze inscriptions; d) Inscribed plaque KR 11; e) stone mould S1673 for square-section rods

The Sn content in Sumhuram's samples appears rather erratic; although not negligible and with some peculiarly high values, for most of the samples it lies quite below the 8–12% range, which is recognized as the optimal one in order to obtain a resistant and workable bronze (e.g. Piccardo *et al.* 2009). The very low Sn content of certain objects can best be explained with the reuse of scrap bronze together with fresh molten copper, given the rare co-occurrence of copper and tin ores (Craddock 1985).

Microstructural analyses also showed that broadly no correlation existed between the production process and the functions of the objects. Likewise, in most instances, there is no evidence of a specific alloy been selected in relation to the programmed reworking and shaping after casting, operations which would highly benefit from the choice of the suitable alloy.

Overall, therefore, the general impression is that of rather inaccurate metallurgical techniques. Besides, no evolution or change in the metallurgical practices was pointed out by the archaeometric study over the long period of occupation of Sumhuram, although the sample was admittedly limited for

such purpose. The different kinds of evidence collected so far at Sumhuram are remarkably coherent about the scale and quality of the metallurgical practice. The shape and dimension of the mentioned stone mould S1673 are, in fact, perfectly fitted to the manufacture of square-section rods as those analysed, that would only necessitate minor shaping after casting. Object dimensions are consistent with the small crucibles retrieved that, moreover, bear traces of the same alloys identified in the objects.

3 A Singular Tradition of Copper Working. The Results from Sumhuram in the Wider Context of the Arabian Peninsula

The culturally and chronologically closest set of comparable data comes from the site of HIH, located on the east side of wādī Beiḥan, some 255 kilometres northeast of Aden (Yemen). The mound, excavated in the 1960s by a team of the AFSM, revealed the remains of an important city, the second capital of the kingdom of Qatabān, occupied from the 11th cent BC down to the 4th/5th cent AD (Van Beek 1969). Metallic samples from several contexts were analysed by X-Ray Spectrography and metallographic observation (Salmon 1969). The results can be discussed together with those from Sumhuram on the basis of the cultural and geographical proximity between the kingdoms of Qatabān and Ḥaḍramawt, but also because the fragments from HIH for which significant data were collected, come from contexts dated between the late 5th cent BC and the final occupation of the city (Van Beek 1969), thus overlapping consistently the chronology of Sumhuram. In terms of general composition, the samples from HIH show similar variability to those from Sumhuram. Noticeably, all the analysed fragments were manufactured using a Cu-Sn-Pb alloy, with lead content ranging from 1 to 42%. Leaving aside the question of the absolute significance of these values, obtained with different techniques, the meaningful data remains the use of leaded bronzes, with a random and generally high content of Pb. It is worth mentioning here the results coming from the analyses of a few, relevant finds which were usefully collected by B. Jändl (2010). Several of the illustrated artefacts, all from SA contexts, are in fact characterized by high lead contents. Pb addition could be due, for these items, to the need of enhancing the molten metal fluidity, but this can be attained at concentrations much lower than 20%, as in the emblematic example of the famous Timnaʿ horse riders. These data bear further support to the suggestion of random and generally high lead content in SA bronzes deriving from recycling and/or from the need to increase the metal mass by adding cheaper alloying elements. The use of Sn in the alloy also appears similar at the two sites: at HIH its rates vary

from 1.1 to 16.7 wt.%, displaying a somehow more regular distribution than at Sumhuram. In that case, their statistic distribution is also much closer to the 8–12% interval which characterizes the best technological choice (Piccardo *et al.* 2009), a figure which might be connected with the location of HIH in the heartland of the SA culture. Minor elements (Fe, Ni, and Z) are present in the HIH samples in quantities that can be explained with impurities in the ores, or with accidental remnants of the flux used during smelting (Salmon 1969). The similarity between the metallurgical practices of the two sites extends to the bad correlation between alloy selection and manufacturing technique.

No other dataset from SA sites is known to the authors. Archaeometallurgical studies are, however, available for sites coeval with Sumhuram in southeastern Arabia and in the Arabian Peninsula as a whole.

A number of finds demonstrate the connections between the opposite sides of the southern Arabian Peninsula during this period (e.g. Mouton 1997). A complete bronze spout adorned with a horse protome, discovered at Sumhuram, finds precise parallels in northern Oman and in the Emirates, in the settlements of Ed-Dur, Samad al-Shan, Mleiha and Salut (Haerinck 1994, Yule 2001, Mouton 2008, Degli Esposti *et al.* 2019). Two coins belonging to the well-known ʿAbiel issues, spread in eastern Arabia (Macdonald 2010), were also discovered as well as a complete "lentoid" flask which again finds parallels at Mleiha, Samad al-Shan and Salut (e.g. Mouton 2008, Yule 2001, Degli Esposti *et al.* 2019). To these finds can be added the large amount of Black and Grey Jars, a type of pottery widely attested in the lower Persian Gulf (e.g. Lecomte 1993, Mouton 2008), and the presence of a few, wheel-turned stone vessel fragments (Buffa 2008), representative of one of the most characteristic production of southeastern Arabia.

At the opposite end of this hypothetic trade route, two bronze coins minted in the Ḥaḍramawt and discovered at Ed-Dur are a sort of counterpart for the ʿAbiel coins found at Sumhuram (Haerinck 1998). At Muweilah, in Sharjah Emirate, a large storage jar, produced with local technique and materials and bearing three South-Arabian letters was discovered (Magee 1999).

A set of thirty-three copper-base artefacts from Ed-Dur was studied by L. Weeks (2004). Located far afield from Sumhuram, in Umm-al-Qaiwain, the site was occupied from the 1st cent BC until the mid-3rd cent AD (Delrue 2006).

In the samples from Ed-Dur, differences from Sumhuram can be seen when it comes to the major alloying elements Sn, Pb and, for a few cases, Zn.

First of all, the use of unalloyed copper is much more widespread at Ed-Dur (9 out of 33 samples). Of the remaining items, twelve have a Sn content between 1 and 12%, while the remaining twelve display a Sn rates ranging from 13 to 47 wt.%. The randomness in Sn distribution is thus broadly comparable

with that shown at Sumhuram, albeit at a different scale. The main differences between the two sites appear when Pb and Zn are considered.[5] In particular, Pb, although surely added intentionally,[6] is much less utilized at Ed-Dur. Nine samples have a Pb content between 1 and 5%, while four others contain from 12 up to 21% of the element.

Completely different is the use of Zn at the two sites. Two samples from Ed-Dur, in fact, were classified as brass, and two other as gun-metal, standing the co-occurrence of Zn and Pb (Weeks 2004). The informed use of brass at Ed-Dur, conversely absent at Sumhuram, is further indicated by the analyses of two daggers and one scabbard fitting, made in an 18–20% zinc brass (Delrue 2006).

Drawing all these considerations together, it seems evident that the metallurgical technology of the two sites was neatly different, and this could mirror the existence of different regional traditions.

Other areas with which southern Arabia had stable contacts were the oases and kingdoms of northwestern Arabia and the fertile crescent (e.g. Macdonald 1997, Avanzini 2016).

Archaeometallurgical studies are limited for this area as well, specifically for what concerns northwestern Arabia. The recent publication of a first dataset from the oasis of Taymāʾ, however, indicates low rates of Pb in the samples, and a general scarcity in the Sn content, which probably mirrors difficulties in the supply of this element (Renzi *et al.* 2016). Also in this case, there is no affinity with the picture obtained from Sumhuram's study.

Overall, the metallurgical tradition which seems to be shared by Sumhuram and H1H, and confirmed by the analyses of more scattered SA finds, appears to be a singular one, for which parallels are not evident in the Arabian Peninsula. It is necessary, therefore, to put forward different hypothesis to contextualise such peculiarity.

4 Looking West? Possible Relations with the Western Side of the Red Sea

The dearth of archaeometallurgical data forces one to take into account pieces of evidence which are not decisive in themselves but, considered as a whole, might suggest the direction for future research.

5 Unfortunately, no metallographic study is available for the Ed-Dur samples.

6 Apart from the Pb content in the objects, too high to be explained with an accidental occurrence in the ore, it has to be mentioned the retrieval of a possible Pb ingot plaque on the site (Haerinck 1998).

Such a case is represented by the data from the site of al-Midamman, on Yemen's Tihama coastal plain, two kilometres inland from the Red Sea coast. There, a small cache of metallic items was recovered, in connection with a group of standing stones, also referred to as megaliths (Keall 1998). The cache was dated to the "Monumental Phase 1" of the site, towards the mid-second millennium BC (Weeks *et al.* 2009). Based on the elemental characterization of the objects from this cache, the inclusion of al-Midamman within a "different sphere of influence than that of the maritime trading centers on the other side of the Arabian Peninsula" was already suggested (Giumlia-Mair *et al.* 2002). Ed-Dur can be considered one of the late heirs of those "maritime trading centers" coeval with the occupation of al-Midamman: its inclusion in an exchange network developed along the Persian Gulf shores is blatantly shown by the remarkable presence of foreign commodities coming from ancient Iran, Mesopotamia, and the Arabian Peninsula (e.g. Haerinck 2003).

This idea was further corroborated by lead isotope analyses conducted on the objects from al-Midamman, with the addition of a few more samples coming from a nearby settlement area (Weeks *et al.* 2009). The results exclude a derivation from northern Oman ores, while a good correlation was found with a possible provenance of the metal from the geological unit known as the Arabian-Nubian Shield, that stretches from western Saudi Arabia and part of coastal Yemen to the other side of the Red Sea, characterizing Northeast Africa from Egypt down to Ethiopia (Stoeser, Frost 2006).

Consequently, these results suggest the possibility either of a local (or generally western Arabian) production of the metal used for the al-Midamman artefacts, or of its provenance from the opposite coast of the Red Sea. In both instances, the site of al-Midamman would be integrated into a regional metal production and exchange system clearly separated from the one existing on the opposite side of the Arabian Peninsula and encompassing the Persian Gulf.

The extension of this hypothesized exchange network intriguingly overlaps a large area of shared cultural elements and unquestionable direct contacts stretching both sides of the Red Sea, emerging as early as the fifth millennium BC, and continuing and consolidating until the first millennium BC (e.g. Fattovich 2004). Several authors underlined, with different interpretations and perspectives, the strong cultural affinity between the communities occupying these areas (e.g. Munro-Hay 1996, Curtis 2004, Keall 2004). What is more relevant in the light of the analytical results from Sumhuram and HIH, is that the driving force behind the intensification of these contacts during the first millennium BC has been suggested to be the search for markets (and lands?) undertaken from the Sabaean kingdom. SA-style monuments were identified on several Ethiopian-Eritrean sites, and along with them, dedicatory inscriptions were discovered that clearly attest to shared writing and rule-legitimating

symbols between the Ethiopian and the SA communities.[7] Although the economic background of these contacts has been recognized in the will of the SA people to access the Ethiopian frankincense and—possibly later—elephant ivory, it is not unfeasible that one should add the research for metals to the equation, either as ores, raw material or finished objects. Once obtained by the Sabaean traders, such commodities were to fluidly enter the SA inland trade network and be delivered to all the major centres, including a faraway "colony" like Sumhuram.[8] The exchange system apparently reflected by the analytical data discussed here can then be seen as the continuation and probable extension inland of a network which had developed over the previous three millennia, originally including obsidian as the main commodity (e.g. Khalidi 2009). The antiquity of these contacts and of the technological traditions that they could have fostered can contribute to explaining why, even when more regular contacts with the other areas of the Arabian Peninsula (including the "Persian Gulf network") were established, there was not a shift toward a different metallurgical technology.

Support to this hypothesis of continuity comes, again, from the site of al-Midamman. While the objects from the above-mentioned cache are dated around the 15th cent BC, in fact, the other objects sampled for lead isotope analyses are dated to the site's "Monumental Phase 2", between c. 1400 and 900 BC (Weeks *et al.* 2009). They are broadly contemporary, therefore, with the early development of the mature SA kingdoms and to the Sabaean entrance in the Tihama. The al-Midamman material culture finds its best parallels in the Ma'layba/Sabir assemblages, which actually, together with a radiocarbon date from a residential context, sets the dating for Monumental Phase 2 (Weeks *et al.* 2009). This culture is clearly distinct from that of the partially coeval SA

7 The nature of these contacts is actually debated, but to discuss it is far beyond the scope of this paper.

8 The possible supply to Sumhuram of "unrefined metals" from Egypt was briefly discussed by C. Tavolieri d'Andrea (2011), despite the lack of sound archaeological evidence. Indeed, Egyptian ports (Berenike, Myos Hormos) had a paramount role within the long-distance trade network that connected the Mediterranean with India, and metal items might have reached Sumhuram and South Arabia in general from there, but the actual provenance of the metal is a different issue. Besides, in the light of the transmarine connection hinted at above, and always at a speculative level, the southernmost port of Adulis would seem more suited for such a role. In the *Periplus*, metal is not listed among the exports from Adulis, but a material called "copper cooked in honey" is mentioned among the imports (Curtis 2004). On the other hand, the beginning of the harbour's trading activity at least around the late first millennium BC, if not consistently earlier (for a discussion of the different hypothesis, see Glazier, Peacock 2007, with bibliography), and its tight relations with the inland region would fit the proposed reconstruction.

kingdoms, but its transmarine affinities (Fattovich 1995, Vogt, Sedov 1998) fit the picture of an ancient and constantly evolving exchange system across the sea. Contacts with SA inland polities are in fact witnessed at al-Midamman by a few features that can be distinguished in the material culture, although recorded with a rarity that connotes them as "exotic" (Keall 2004). Such a broad scheme of a regional exchange system which involved metal production and use, encompassing the Yemeni and the Ethiopian-Eritrean highlands on both sides of the Red Sea and possibly shifting its centre to the heartland of the SA kingdom in the first half of the 1st millennium BC, could offer a tentative explanation for the only, minor variation within the Sumhuram results. Samples from the earliest contexts (period 1) are in fact the only group (indeed limited) for which there is an apparently more accurate control over alloy composition (Degli Esposti *et al.* 2018). In fact, tin does not show such dramatic variations as it displays in general, and Pb is kept constantly close to the rate of 2 wt.%. The distance from the centre of the kingdom—and thus of the exchange system—and the gradual isolation of the site, probably enhanced after the kingdom of Ḥimyar subdued that of Ḥaḍramawt, could account for a reduced supply of metal and increased recycling.

This picture is also consistent with the absence of evidence for copper smelting operations at Sumhuram and of suitable ore deposits in the region, at least standing to the available survey results.[9]

5 Conclusive Remarks

On the basis of the results of compositional and microstructural analyses on bronze objects from Sumhuram, discussed in the context of SA bronze production, the following conclusions can be put forward:

1. The metallurgical procedures conducted at Sumhuram were far from standardised. They display a random use of the available metal, probably coming from repeated recycling with the possible addition of "fresh" copper and lead. Besides, there is generally no good correlation between the chosen alloy composition and the procedure needed to obtain the final piece. The metal was surely processed at the site but the scale of this production, at least for what concerns copper-base alloys, was rather small, which would be commensurate with its quality, seemingly indicating non-specialized craftsmanship as well as supply restrictions. Further

9 L. Chiarantini, personal communication 2012.

work is needed to enlighten the contemporary situation of iron-working at the site.

2. The evidence, despite scarce, allows the speculative reconstruction of a large, regional metal production and exchange system, embedded in a more general contact network which integrates South Arabia and the opposite side of the Red Sea, namely southern Eritrea and Ethiopia. This network remained separated from others which were active in the Arabian Peninsula, and remarkably from the one centred on the Persian Gulf. With an embryonic phase that can be traced back to the 5th millennium BC, this network consistently developed around the mid-2nd millennium BC and further evolved towards the turn of the millennium, when one starts to gather conspicuous evidence of cultural contacts and influence, mainly directed from Saba to the Ethiopian-Eritrean highlands but later to change direction with the Aksumite invasion of South Arabia. Given the political and economic importance gained by the classic SA kingdoms, a shift of this network's centre towards inland Yemen during the early first millennium BC seems possible. Sumhuram thus appears to be integrated into the large sphere of influence of the classic SA kingdoms not only from a political point of view (founded by the kingdom of Ḥaḍramawt, it likely fell under the Ḥimyarite control after the Ḥaḍrami defeat) but also from that of the metallurgical tradition. Data from Sumhuram and Hajar Ibn Ḥumayd indicate, in fact, a neatly different metallurgy from that of other sites of the Arabian Peninsula. The distance of Sumhuram from the centre of this system could account for its apparent need to rely on recycled metal, which some feeble elements indicate as becoming more impellent in the later times.

Finally, one must underline that the archaeometallurgy of the SA kingdoms is still in its infancy, and more analytical data are needed, as well as new projects concerning the metal production on the Ethiopian and Eritrean highlands, necessary to verify whether the apparent connection between the opposite sides of the Red Sea in terms of raw materials is also reflected in similar alloying practices. Such data could complement and possibly change the interpretation given here, that has to be considered a working hypothesis.

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