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Advances in UAE Archaeology

Proceedings of Abu Dhabi's Archaeology Conference 2022

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Advances in UAE Archaeology details the results of new excavations conducted across the United Arab Emirates over the last few years. These excavations have revealed a wealth of new data on all periods of UAE archaeology from the Palaeolithic to the recent past. Some of these discoveries have filled in important gaps in our knowledge, while others have fundamentally revised what we thought we knew already. For example, the Marawah Island excavations have added a new facet to our understanding of the Neolithic period by revealing intriguing and hitherto unknown funerary rituals.

Excavations in Al Ain in the emirate of Abu Dhabi continue to reveal extraordinary evidence of *falaj* irrigation, stretching back 3000 years. The ubiquity of this system across this oasis city further validates its status as a UNESCO World Heritage Site. Of particular importance is the discovery of extensive remains from the Late Pre-Islamic period, a significant time in history that has been best revealed in the excavations at Mleiha in the emirate of Sharjah.

The research presented here was conducted by specialists from across the world working alongside an ever-growing cadre of Emirati archaeologists who will take the lead in the coming years in revealing more of this country's extraordinary archaeology and history.

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Iron Age copper production and the 'ritual economy' of Saruq al-Hadid (Dubai, UAE)

Lloyd Weeks, Tatiana Valente, Kristina Franke, Fernando Contreras, Mansour Boraik Radwan and Hassan Zein

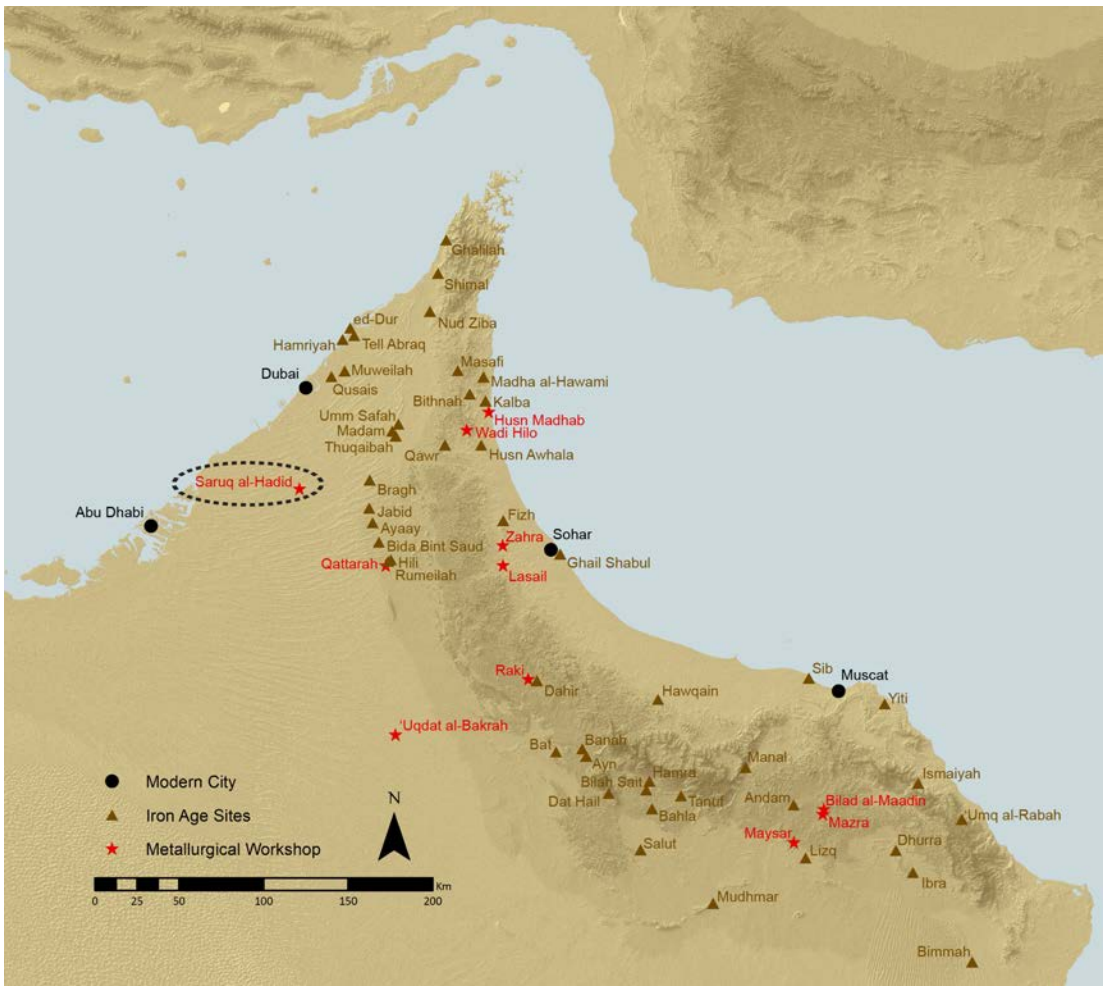
Abstract: The site of Saruq al-Hadid has significant potential to enhance our understanding of copper metallurgy and its social role in the Iron Age societies of Southeastern Arabia. The metallurgical evidence from the site indicates Iron Age copper production activities that included metal smelting and refining, alongside the fabrication of finished artefacts from local and imported materials through casting and working. Many of the products of this metallurgical activity were recovered from contexts that likely represent cultic activity, in particular the deposition of votives to a 'snake deity'. Alongside these acts, copper artefacts were also a component of ritual performances of social cohesion that would likely have worked to legitimise the authority of those who controlled the production and deposition of such materials. The broader organisation and significance of copper production at the site can be effectively interpreted through the theoretical lens of a 'ritual economy', which situates this technology within the socially constructed knowledge, beliefs and practices of Early Iron Age society in Southeastern Arabia.

Keywords: Iron Age, Southeastern Arabia, copper metallurgy, social cohesion, ritual economy, snake cult

Introduction

Saruq al-Hadid is a site of long-term, persistent, seasonal human activities stretching from the Neolithic period into the Early Islamic period. Situated on the southern border of Dubai, on the fringes of the Rub' al-Khali desert (Figure 1), the site has been explored by a number of archaeological teams since its first discovery in 2002 (Valente *et al.* 2020; Weeks *et al.* 2019b). This research has served to clarify the nature and extent of human activities at the site and their changing nature through time, although a coherent and nuanced understanding of this complex and enigmatic site remains a focus of research.

Here, we present a summary of ongoing research into the nature of practices related to copper metallurgy at the site — a key component of the activities undertaken there in the Iron Age and later periods — and explore the social factors that contoured metallurgy and craft production at the site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and shaped the deposition of its material remains. In doing so, we draw on excavations undertaken principally by the Dubai Municipality, the Sanisera Archaeological Institute (SAI) and the Saruq al-Hadid Archaeological Research Project (SHARP) in two areas of the site: Area F/G and Area 2A, which sit approximately 100 metres apart (Figure 2), and on archaeometric analyses of metallurgical residues and copper-base artefacts from Area F/G undertaken by SHARP. The paper begins with a summary of the development of the archaeological sequence of the site, followed by a review of the variety of metallurgical materials and practices undertaken there, as reconstructed from macroscopic and archaeometric analyses. Subsequently, the 'ritualisation' of copper production and deposition at Saruq al-Hadid is considered, and the nature of craft activities at the site is conceptualised within the framework of a 'ritual economy'.

The archaeological deposits of Saruq al-Hadid

Saruq al-Hadid sits in a desert environment, amidst aeolian sand dunes, at the north-eastern limits of the Rub' al-Khali desert. Throughout its long history, the site does not exhibit evidence of permanent settlement but rather of seasonal occupation. This aspect is evidenced in the immediate vicinity of Saruq al-Hadid from the Neolithic period, when (semi-)mobile communities moved seasonally to the area to graze and water their domestic animals, exploiting the improved vegetation cover caused by the Early Holocene humid period.

As climate deteriorated from the Late Neolithic into the Bronze Age, seasonal hunting activities took place at the site (Roberts *et al.* 2018). Postholes, hearths, potsherds and a large bone midden in Area F/G are testimony of the occupation at this time. Palaeoenvironmental data suggest the site may have looked somewhat different from today, with a less dense and deep coverage of sand dunes and with a denser vegetation of shrubs, acacia and *ghaf* trees (Valente *et al.* 2020: 171-177; Weeks *et al.* 2017: 38-40). Water, which still flows abundantly in underground aquifers (Rizk and Alsharhan 2003), could be reached through wells. Several were found on-site, although only one could be dated securely to the Umm an-Nar period, remaining in use until the Iron I period (Valente *et al.* 2020: 172).

Similar environmental conditions continue throughout the Iron Age. However, it is evident from the archaeological record that dune accretion accelerated and further transformed the landscape during this period, with vegetation progressively diminishing (Valente *et al.* 2020: 173), perhaps due to deforestation actions for charcoal production, although this is not yet proved (Parker and Goudie 2008: 468). At this time, the site becomes a focus for metallurgical production, alongside other craft, cultic and community activities (Weeks *et al.* 2019a; Weeks *et al.* 2019b; Valente *et al.* 2020). In the Saruq-53

Figure 1 (opposite, top): The location of Saruq al-Hadid and other early Iron Age sites in Southeastern Arabia. (© Tatiana Valente)

Figure 2 (opposite, bottom): Drone image of Saruq al-Hadid, looking south-west, showing Area 2A (foreground) and Area F/G (background). (© Qutaiba Al Dasouqi)

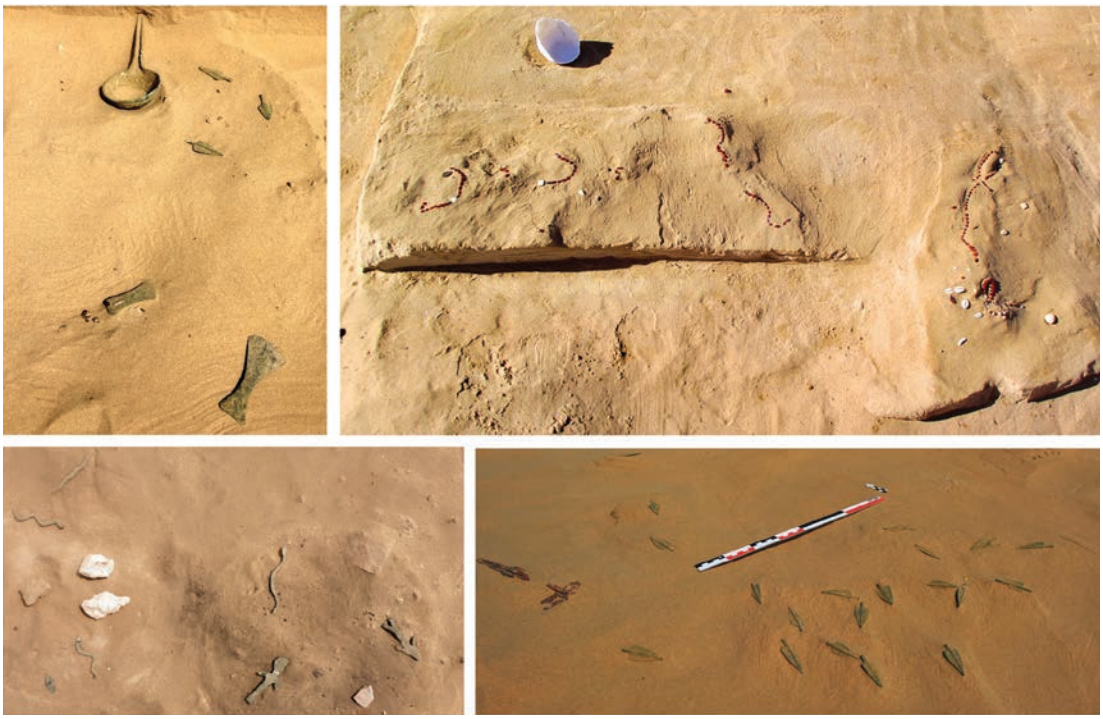


Figure 3: Examples of ceremonial deposits from Areas 2A and G. (© Tatiana Valente and Fernando Contreras)

area, about 500 m to the east of Areas F/G and 2A, dense deposits of charcoal have been recovered from excavation; these are dated to the Iron II period and may represent the remains of charcoal production at the site. Although the site appears to have possessed several fundamental resources necessary to support a metal industry, most importantly water and wood for charcoal, the copper ore had to be brought in from at least 100 km away, where the nearest sources are located in the Hajar Mountains. Transport of ore over such long distances is rarely documented in the archaeological record, and where practised it typically characterises the very earliest periods of extractive metallurgy (Hauptmann 2007: 14).

From the stratigraphic sequences identified in Area F/G of the site, the first ritualistic deposits appear during the Iron I period, c. 1250–1000 BCE (Horizon III [Weeks *et al.* 2019b: Fig. 8; cf. Valente *et al.* 2020: 172]). They are marked by the presence of 'incense' burners decorated with snake appliqués, comparable to those observed in Masafi, for example (Benoist *et al.* 2015: 25, Fig. 4, 1-3). Subsequently, an intensive occupation throughout most of the Iron II period is observed (Weeks *et al.* 2019a; Contreras *et al.* 2017), both in the shape of 'ritualised' deposits in Areas F/G and 2A (Figure 3), and of metal production in Area 2A, where multiple combustion structures, raw metal lumps, metallurgical residues and scrap have been identified.

In Area F/G, activities involving the deposition of copper-base artefacts and other materials within possible ritual contexts are observed in the shape

of relatively thin depositional lenses with rich material remains, separated by dune deposition indicating periods of abandonment, the duration of which is difficult to determine. In Area 2A, in contrast, ritualised deposition appears to have occurred more consistently, occupying a single deposit of c. 50 cm in depth, suggesting continuous (albeit seasonal) deposition of objects within a relatively circumscribed time period. It is important to note that in Area 2A these ritual deposits are stratified above deposits with abundant metallurgical debris, although mostly concentrated in a central zone with no combustion structures below (Valente *et al.* 2019: Fig. 2). Despite the sandy stratigraphy, and the prevalence of complex and deflated deposits, it is apparent that social activities characterised by ritual deposition tended to occur in raised areas of the site, where substantial dunes had already accumulated by the Early Iron Age. This is seen in both Area 2A and Area F/G, where the existing high point of the Bronze Age midden appears to have been a focal point for ritual activities.

Finally, the top horizon (or 'slag layer' as it is alternatively known) contains discarded materials datable from the Iron II period all the way to the Pre-Islamic and Early Islamic periods (Weeks *et al.* 2019a; Contreras *et al.* 2017). The chronological development of this archaeological horizon is challenging to disentangle due to its complex natural and cultural formation processes. Based on the available radiocarbon evidence, the site appears to have been progressively abandoned before the beginning of the Iron III period, possibly due to worsening environmental conditions of continued dune accretion and reduced vegetation cover. After this period, the site was visited sporadically for metal scavenging and recycling, thus creating the top horizon of accumulated discarded material and metallurgical debris, before the resumption of more substantial copper smelting activities in the Early Islamic period (Stepanov *et al.* 2019; Weeks *et al.* 2019a: 7; Valente *et al.* 2020: 177). Much of the metallurgical assemblage discussed in this paper derives from this uppermost horizon at Saruq al-Hadid. Despite absence of clear chronostratigraphic sequencing in Area F/G, the well-stratified remains from Area 2A and a range of additional archaeological and archaeometric data allow the identification of the major metallurgical production activities undertaken at the site during the Iron Age, as discussed in more detail below.

As a final point of consideration, we note that Saruq al-Hadid is distant from major contemporary settlements of the Iron Age (Figure 1). Although significant surface scatters of Iron Age pottery are known from c. 28 km to the east, at Al-Sooq (Qandil 2005), the nearest sedentary Iron Age settlements comprise a string of sites about 40 km to the east, stretching northwards from the Al Ain Oasis along the piedmont towards Al Madam (Al-Tikriti 2010). The oasis of Al Ain, with its concentration of Iron Age sites, is c. 70 km distant, as are the major sites of Al Qusais and Muweilah closer to the coast. Saruq al-Hadid is spatially separate from any of these sites, although they share

similar assemblages of cultural material (Karacic *et al.* 2018; Lombard 1985; Taha 1981; Valente *et al.* 2023; Córdoba 2016).

Thus, Saruq al-Hadid's location is liminal both in terms of the wider Iron Age settlement system and in relation to the metallurgical resources that were exploited there. Here, we argue that its social role in the Iron Age society of the region is key to understanding the existence, location and activities undertaken at this enigmatic site. Saruq al-Hadid's important material and metallurgical assemblages, discussed in this paper, provide further insight into this matter.

Copper production at Saruq al-Hadid: A brief summary

The range of evidence

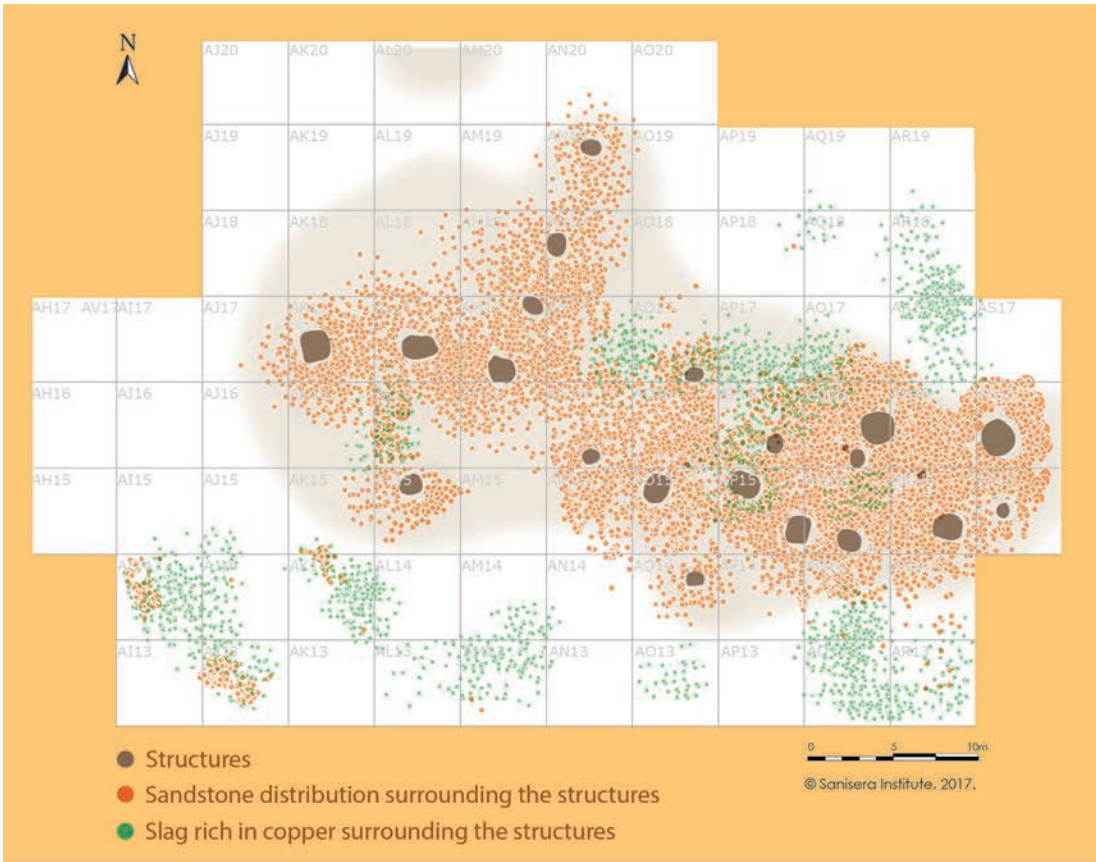
Saruq al-Hadid has produced an abundance of material remains related to metals and metallurgy, including hundreds of kilograms of ferrous remains, many hundreds of gold and silver artefacts, and smaller quantities of artefacts in lead and antimony (Boraik Radwan 2018; Weeks *et al.* 2017). Most abundant among the metal remains from the site, however, are those related to the extraction and refining of copper and the production of copper-base artefacts. As described above, copper smelting slags, showing a variety of morphologies and technologies, are a dominant component of the upper deposits of the site, concentrated by natural and human action into dense deposits that allowed the first identification of the site and its archaeological significance. Residues from subsequent stages of the production process, including the refining of the raw copper and the production of ingots, have also been recovered in substantial numbers, alongside evidence that this metal was melted, possibly alloyed, cast and worked to produce a wide range of finished artefacts. Such artefacts are known in their thousands from the site, and many appear to have been produced there.

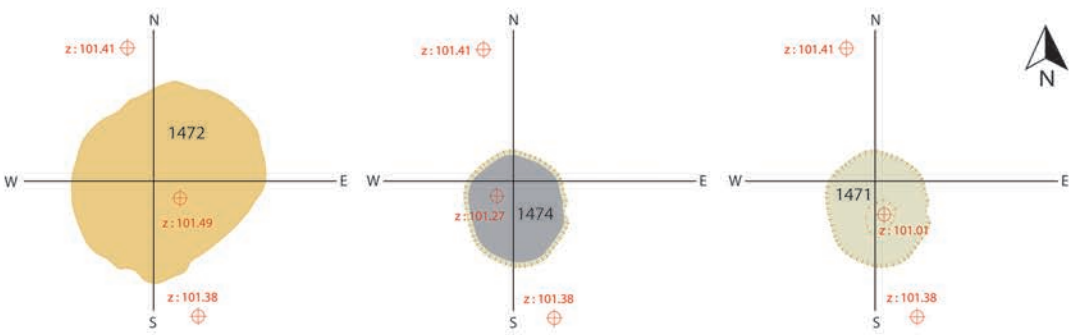
As discussed above, the chronology of these activities can be difficult to reconstruct with certainty due to the complex formation processes that characterise the site (Weeks *et al.* 2019a; Valente *et al.* 2020). Based on the stratigraphic position of metal artefacts and residues, it seems clear that high-temperature metallurgical activities did not begin there before the Early Iron Age, although copper-base metal artefacts (principally arrowheads) are reported in modest numbers from the Wadi Suq period to Late Bronze Age deposits of Horizon IV in Area F/G (Weeks *et al.* 2017). A broader range of metal artefacts characterises Iron I period deposits in Area F/G, dated to c. 1300–1000 BCE, when copper artefact numbers and types expand and diversify to include production residues, alongside the earliest evidence for ferrous remains and precious metal artefacts, as well as cultic paraphernalia (Weeks *et al.* 2019b: Fig. 8). By the Iron II period in Area F/G, consistently

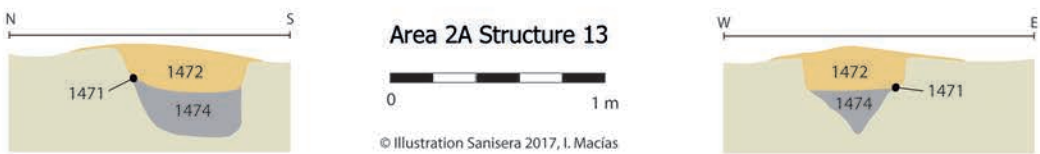
radiocarbon dated between c. 1000–800 BCE, copper production residues and artefacts are abundant, and include smelting slags and fragmentary furnace remains, raw copper and refining debris, ingots and apparent casting spills. The sequence in Area F/G is capped by dense, deflated deposits (Weeks *et al.* 2019b: Fig. 11 and above), within which copper slags are the major artefactual component, alongside other semi-products, production residues and copper-base artefacts. Direct radiocarbon dating of charcoal from copper slag and thermoluminescence dating of technical ceramics (the lining of copper smelting furnace walls) suggest that these remains span a huge time period from the Early Iron Age, c. 1000–800 BCE, through the Late Pre-Islamic period and into the Early Islamic period in the 9th to 10th centuries CE (Weeks *et al.* 2019a: Fig. 11).

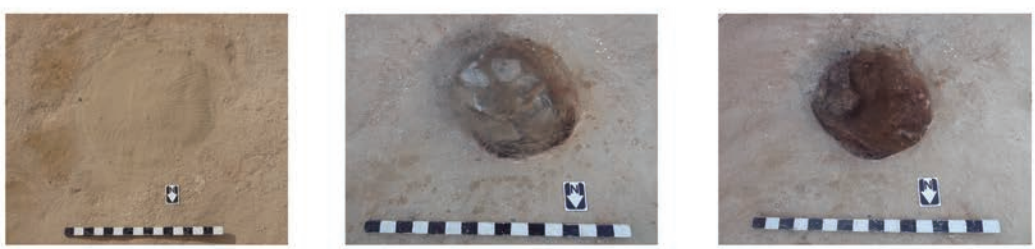
However, many of the metallurgical remains from Area F/G are in secondary or higher-order contexts affected by human action and the complex taphonomy of the burial environment at the site; coherent collections of metallurgical debris and pyrotechnological installations have not been recovered from this area of the site. Although the chronology of finished artefacts can be reasonably well defined through typological studies, allowing the florescence of metal production and deposition in the Early Iron Age to emerge clearly from the archaeological evidence, the metallurgical debris is typically not as amenable to such studies. Some well-preserved slags from Horizons I and II can be typologically dated by comparison to material known from other smelting sites in the region and thus positioned within the long history of metallurgical developments across the Oman Peninsula (e.g. Weisgerber 1980; 1981; Hauptmann 1985; Goy 2019), but many of the material remains are highly fragmentary and chronologically undiagnostic according to either their morphology or production technology. Thus, the development of an overarching *chaîne opératoire* for Iron Age metallurgical production in Area F/G is challenging due to the possibility that exemplars of particular metallurgical residues and technologies might be erroneously drawn from multiple, technologically divergent production periods. Also to be factored into the discussion is the possibility that many materials from the site, very likely metal artefacts but possibly also metallurgical debris, may have been brought to the site from elsewhere, and may thus represent off-site craft practices.

A better interpretation of the metallurgical assemblage from Area F/G, and the isolation of the Early Iron Age technological corpus, thus depends heavily on the excavated evidence from Area 2A, 100 m to the north-east, which provides the clearest evidence for in-situ metallurgical activities that has so far been documented at Saruq al-Hadid (Valente *et al.* 2020: Figs. 5-8; Contreras *et al.* 2017). Numerous absolute dates indicate that this area was in use between c. 1200–800 BCE, with rare dates extending into the 8th or 7th centuries BCE. As shown in Figure 4, Area 2A contains multiple pits dug









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into the ground surface. Although they are themselves free of metallurgical debris, and some seem too large to have been effective for metallurgical operations, these combustion structures and the site area in general can be linked to metallurgical activities through the identification of abundant charcoal, and thousands of copper-rich refining and production residues and scrap metal pieces in the immediate vicinity (Figure 5). They also bear close comparison to pits recorded at the Early Iron Age copper processing site of 'Uqdat al-Bakrah in Oman (Genchi and Giardino 2018: 17-23, Figs 3.9-3.18).

Figure 4 (opposite): Upper: Pits in Area 2A and their spatial association with abundant copper production residues. Lower: An example of the small pit and deposits recorded as Structure 13. (© Manuel González, Ismael Macias and Anna Zuber)

Figure 5 (above): Examples of metallurgical residues from Area 2A. (© Anna Zuber and Tatiana Valente)

Analytical approaches

The metallurgical remains from Saruq al-Hadid are the subject of an ongoing programme of archaeometric research. This research aims to provide a clearer understanding of the nature of the extractive metallurgical processes

that were undertaken at the site, the technology of metal refining, alloying and artefact fabrication, the provenance of raw materials, and the social, political and economic systems that supported these activities.

Field recording of the metallurgical assemblage employed traditional approaches to typological classification and quantification of different categories of remains, supplemented by the use of portable X-Ray Fluorescence (pXRF) analyses for non-invasive qualitative assessments of artefact composition and the selection of materials for further analyses. A subset of the examined metal-related materials was exported for an integrated suite of materials analyses. This included quantification of bulk major, minor and trace element composition, optical metallography of mounted specimens to determine fabrication techniques, and measurement of lead isotope ratios for provenance determinations. The preliminary results of these studies are drawn on in the following discussion, although it is noted that material from Area 2A has not yet been incorporated into the analytical programme.

Primary copper extraction during the Iron Age: smelting slags and furnace fragments

Macroscopic examination of the slag from Saruq al-Hadid indicates a diversity of types, but with a dominance of furnace slag (i.e. those that solidified within the furnace) over tap slag (i.e. those that solidified outside the furnace). The best-preserved example of a furnace slag recovered from the site is SF21468, from a Horizon II context in Area G (Weeks *et al.* 2019a: Fig. 9). This fragmentary piece has a surviving diameter of c. 20-25 cm, and is characterised by a rough upper surface, convex sides and a flat lower surface that represents the original interface between the slag and the matte (concentrated copper-(iron)-sulphides) and raw metal that formed towards the base of the smelting furnace. With a diameter of c. 15 cm, this interface has dimensions similar to the 'ingot-shaped raw material' (SF21467) found in direct association with it in Area G, which consisted of a large layer of matte with a thin layer of black copper (see below) at its base. This particular find may have been the result of an unsuccessful smelting operation, but the existence of several other likely raw metal ingots known from excavation that could weigh up to c. 6 kg supports the evidence for smelting operations on the site.

Although surviving fragments of furnace lining are commonplace at the site — typically displaying slag-encrusted inner surfaces and highly eroded outer surfaces — clearly identifiable components of smelting furnace superstructures are comparatively rare. A good example is SF27901, a slightly inverted rim fragment of mineral-tempered clay, with an outer rim diameter of c. 24 cm increasing to 26 cm at its lower end (Weeks *et al.* 2017: Fig. 20); in its diameter, it is comparable to other diagnostic furnace wall fragments. Although the height of the furnaces used at the site cannot be reconstructed

from currently available evidence, it appears that cylindrical clay furnaces that narrowed towards their top with a rim diameter of c. 18-30 cm were used to smelt copper at the site during the Early Iron Age, sitting atop a pit in the ground where the bulk of the furnace slag formed above the primary metallurgical product of the smelt — comprising copper matte and raw metal. The nature of the air supply to these furnaces remains somewhat unclear. No tuyères have been recovered from the site, but many furnace wall fragments exhibit holes of c. 2 cm diameter that allowed for the inflow of air into the smelting chamber (Weeks *et al.* 2017: Fig. 20; Boraik Radwan 2018: 44). These may have facilitated a natural draught into the furnace, as known for example from prehistoric metallurgical production in other regions of the Old World (Hauptmann 2007: 229-232).

The Iron Age date of this extraction technology is supported by the stratigraphic position of key remains (Area F/G, Horizon II), as well as several typological parallels with excavated EIA metallurgical remains from Masafi-1 (e.g. Benoist *et al.* 2015: 28–30, Fig. 7). This dating is further confirmed by the recent discovery of typologically comparable smelting remains within the Early Iron Age settlement at Hili-14 in Al Ain, Abu Dhabi (D. Eddisford, *pers. comm.*) and by a broader typological resemblance to smelting slags from the EIA site of Raki in Oman (e.g. Goy 2019: 202-203, Fig. 115).

A second copper extraction method is evidenced by two conical slag blocks from the site with tapped upper surface textures, gravel or sand burned into their outer/lower surfaces, and a diameter of c. 30-40 cm. These slag blocks can be associated with a fair amount of tap slag and so-called dense slag found in Areas F/G and 2A. Here, the produced copper was separated from the slag by tapping it out of the furnace into a separated pit. The shapes and sizes of the furnaces remain unknown, since no diagnostic furnace-lining fragments have been clearly associated with this method so far. This smelting method is known from later periods in the region (Weisgerber 1981; Hauptmann 1985) and analysed associated slag showed on average significantly lower amounts of trapped copper than the furnace slag, confirming an improved technology in copper extraction during later periods of copper smelting at Saruq al-Hadid.

Analyses of polished sections of primary smelting slags (Figure 6) display mineralogical associations typical for ancient primary copper smelting slags, including abundant Fe-rich olivines (principally fayalite) alongside iron oxides in a glassy matrix. Inclusions within the slag matrix are primarily of copper(-iron)-sulphides, alongside larger matte phases, metallic copper prills and often also unreacted and semi-reacted fragments of the original sulphidic copper ore charge. The inclusions thus demonstrate that smelting activities were focused on the reduction of sulphidic copper ores, a technology that, in Southeastern Arabia, is first documented as the dominant metallurgical extraction technology in the Early Iron Age.

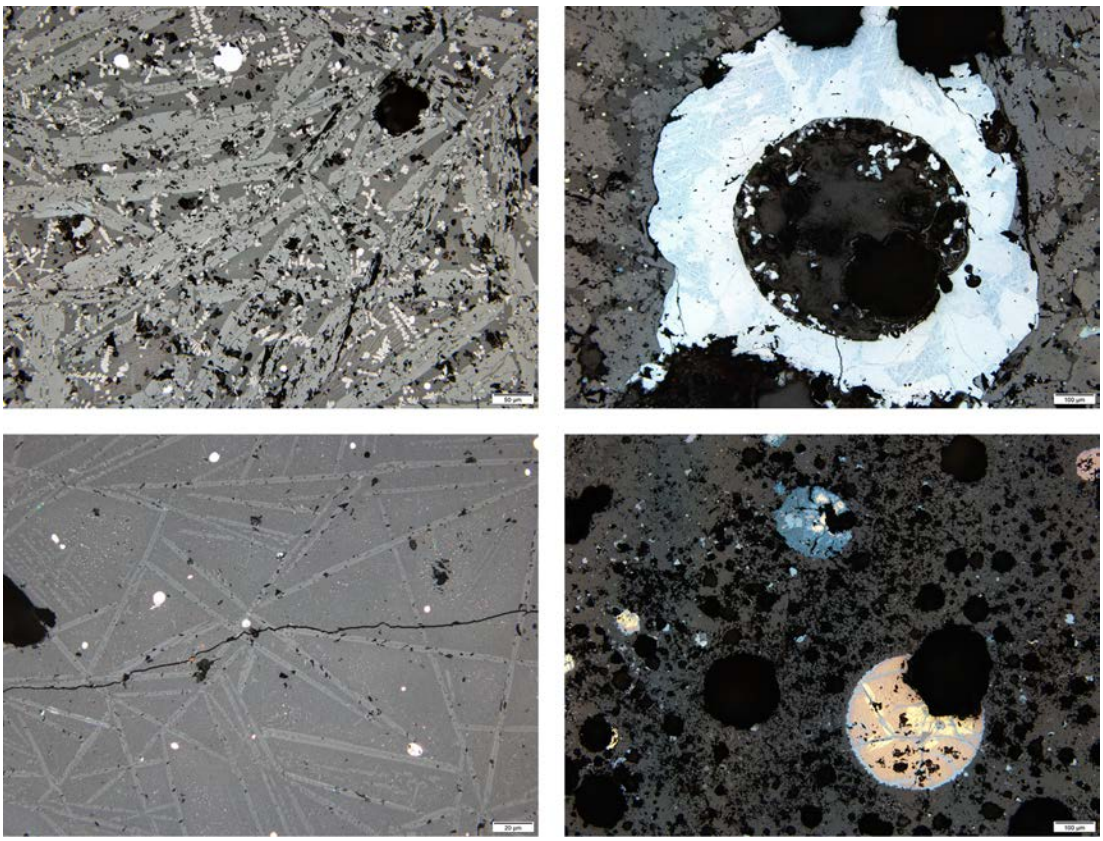
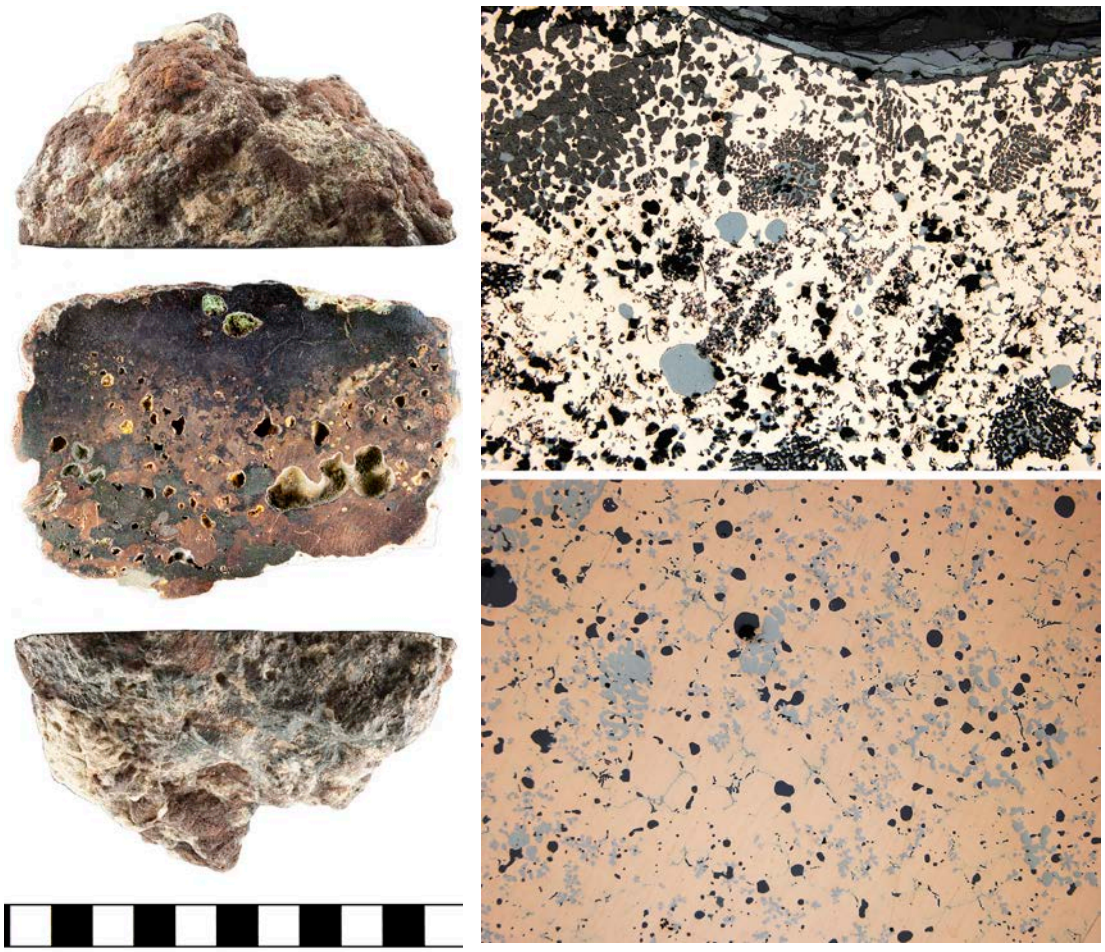


Figure 6: Microstructures of slags from Saruq al-Hadid. Top left: SF22481 showing skeletal fayalite of different sizes (mid grey) with dendrites of iron oxide (light grey) and prills of copper sulphide (pale blue-grey) and copper (white) in a glassy matrix (dark grey) (scale bar 50 µm). Bottom left: SF22449 showing long skeletal fayalite laths (mid grey) in a glassy matrix (dark grey) with copper prills (yellow-white) (scalebar 20 µm). Top right: SF22776 showing matte (copper-iron-sulphide) forming in the slag (scalebar 100 µm). Bottom right: SF22432 showing fragments of partially reduced ore (bright orange-blue) in a lath to massive fayalite slag with rare copper prills (scale bar 100 µm). (Micrographs: T. Eley)

Raw copper, matte and refining in the Iron Age

The archaeological evidence from Saruq al-Hadid for the primary and intermediate products of smelting operations — matte, raw copper, refining debris and ingots — is abundant. The exploitation of sulphidic copper ores (see above) is reflected in the presence of numerous pieces of matte that were produced in the primary smelt alongside, and sometimes inter-mixed with, raw copper. A good example of this is provided by specimen SF38149 (Figure 7), which shows a section through a large, disc-shaped 'ingot' of matte and raw copper produced during a (primary) smelting operation. The artefact has a rough exterior with areas of typical green corrosion products but also abundant rusty-red areas indicative of its high iron content. The polished section reveals an upper area with a shiny dark-grey metallic appearance, representing a layer comprised predominantly of matte. Below this, but intermixed with it, is a layer rich in reddish metallic copper (and some metallic iron), which has separated from the matte during the smelt due to its greater density. The separation is imperfect, and the raw copper metal includes matte as well as pieces of smelting slag (dark areas within the metal), alongside large pores.

Microscopic examination of the raw copper from Saruq al-Hadid indicates the presence of abundant inclusions of (corroded) metallic iron and copper(-iron)-sulphides, sometimes amounting to 30-40 wt% of the specimen



(Figure 8). This material can be classified as 'black copper', a primary smelting product that is well known from other LBA/EIA smelting sites in Southwest Asia (Moorey *et al.* 1988; Roman 1990). This raw metal was subsequently re-melted and thereby refined for the stepwise removal of metallic iron content, and then cast into copper ingots (Merkel 1990), numerous examples of which are known from the site (e.g. Weeks *et al.* 2017: Fig. 21; Boraik Radwan 2018: 42-43). The copper ingots, typically of rough plano-convex shape with diameters of c. 10 cm and weights of c. 1 kg (although 'miniature' versions are also reported), commonly have sulphur concentrations of less than 1 wt% and iron concentrations of c. 4 wt% or less. Residues from these secondary re-melting and refining processes, comprising amorphous lumps of metallurgical waste (refining slag), are well attested in Horizons II-I in Area F/G. The evidence of pyrometallurgical installations from Area 2A is critical in documenting the on-site processing and refining of raw copper rich in iron impurities, as attested by the rusty corroded appearance of many metalworking residues from this area (Figure 5). Based on an experimental study by Merkel (1990), refining may have been undertaken in only three to four steps to reduce the metallic iron content dramatically. During

Figure 7 (left): The raw copper 'ingot' SF38149, showing its rough, disc-like shape, surface corrosion indicating a high iron content, and (in section, centre) the presence of poorly separated layers of matte (upper) and raw copper, iron and slag (lower). (Photographs: L. Weeks)

Figure 8 (right): The microstructure and composition of raw 'black copper' smelted at Saruq al-Hadid. Top: SA23156 showing abundant corroded iron inclusions and copper-sulphides. Bottom: SA22772 showing abundant metallic iron (light blue) and copper sulphides (grey). (Micrographs: K. Franke)

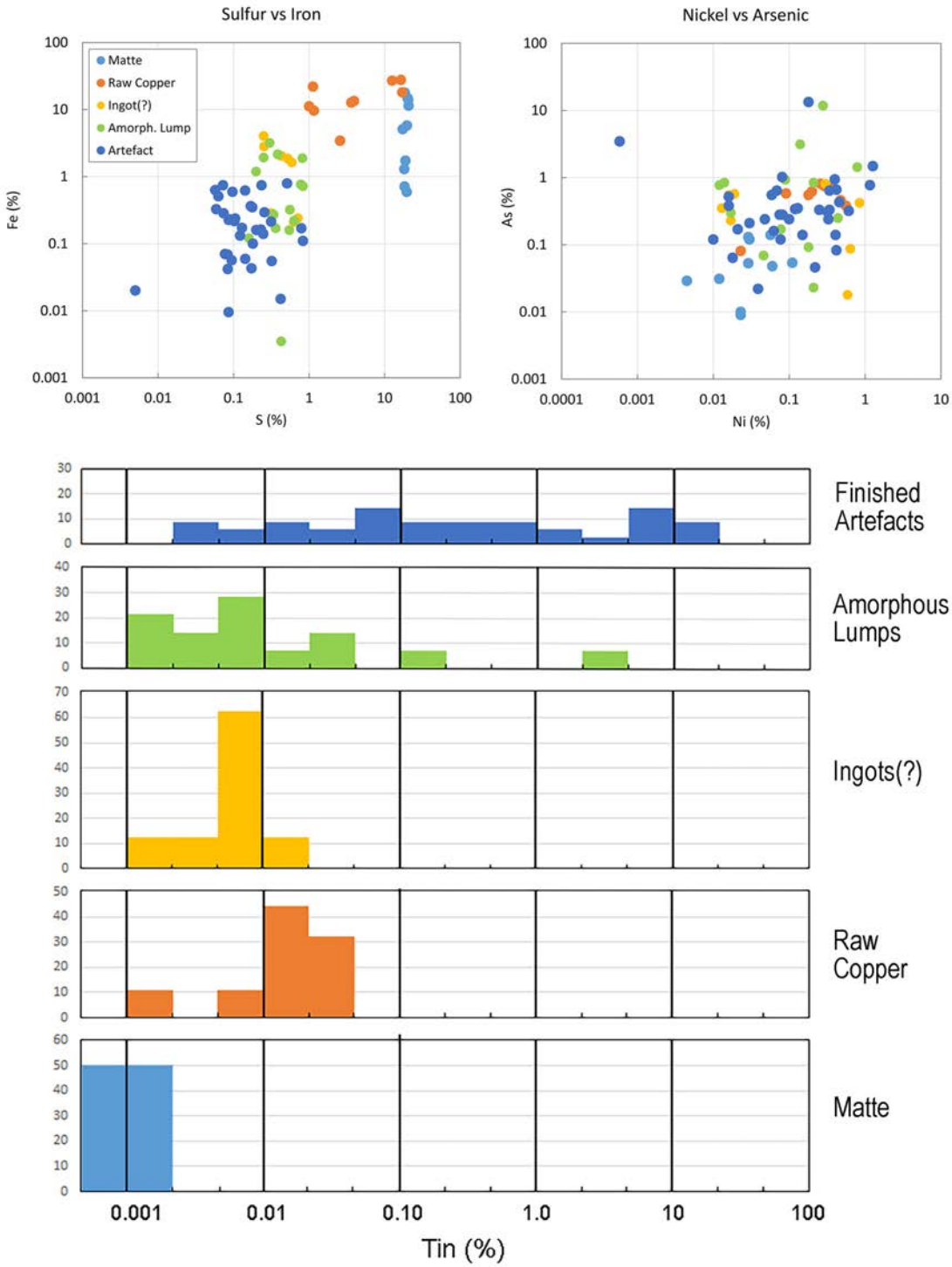


Figure 9: Compositional data for metallurgical remains (n=76) from Saruq al-Hadid, showing scatterplots of iron (Fe) and sulphur (S) concentrations (upper left), arsenic (As) and nickel (Ni) concentrations (upper right), and histograms of tin (Sn) concentrations (lower). (Images: L. Weeks)

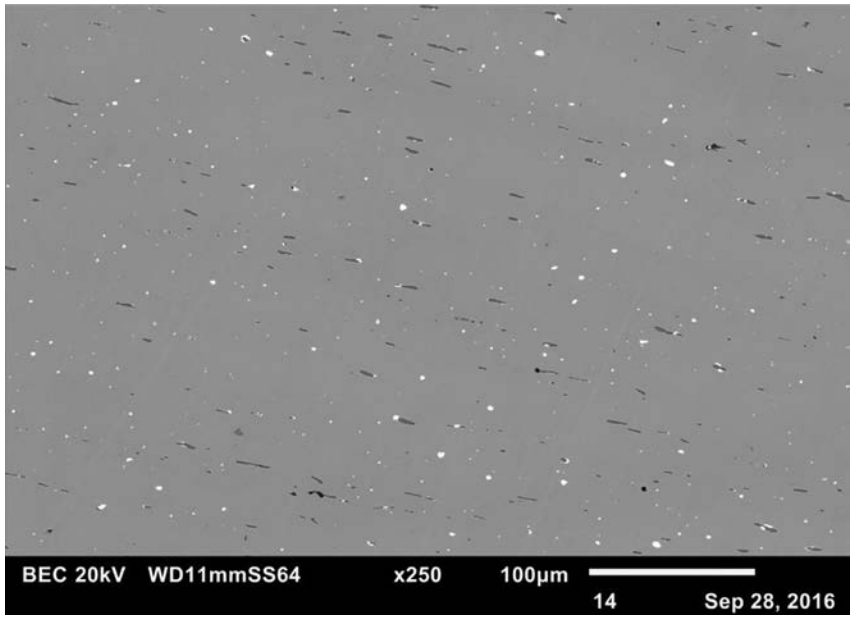


Figure 10: SEM image (backscattered mode) of sample BF27644, a bronze artefact with c. 11% Sn and minor concentrations of As and Ni. The sample contains c. 0.47% Pb, which can be clearly seen in the image as abundant small, white dots. (Image: K. Franke)

melting of the copper metal for casting, additional iron content may have been removed which is evident by the on-average lower iron (and sulphur) content within finished artefacts in comparison to ingots from Saruq al-Hadid (Figure 9).

Final products: Iron Age artefacts, production residues and recycling

The record of finished copper-base artefacts from Iron Age Saruq al-Hadid is superabundant, incorporating many thousands of individual items including arrowheads, daggers, bracelets/anklets, vessels, braziers, fishhooks, anthropomorphic and animal figurines and many other artefact categories (Boraik Radwan 2018: 51-85; Weeks *et al.* 2017: Fig. 19; Contreras *et al.* 2017: Fig. 7). These assemblages come from Horizons I and II in Area F/G, and from Area 2A, and are securely dated to the Early Iron Age by consideration of their stratigraphic position, a large number of radiocarbon dates and many typological parallels to EIA sites across Southeastern Arabia.

At least some of these artefacts were manufactured at Saruq al-Hadid, although it is difficult to know what proportion of the entire artefactual assemblage was produced on site. Artefact production at the site is indicated incontrovertibly by the pyrometallurgical installations and production residues found in situ in Area 2A and is strongly suggested by the recovery of unfinished cast artefacts from the site, including arrowheads and an elaborate socketed axe or halberd (e.g. Boraik Radwan 2018: 45). In addition, compositional analyses of artefacts and production residues from Area F/G indicate similarities between ingots, amorphous lumps and spills, and finished artefacts from Saruq in terms of their arsenic and nickel concentrations (amongst other trace and minor elements), while also documenting the presence in finished artefacts and production debris of alloying elements such as tin

and occasionally zinc, antimony and lead (Figures 9, 10). In contrast to the increased concentrations of these elements within production debris, they occur only at trace concentrations in the raw copper produced at the site. Tin and lead, in particular, are likely to indicate the use of alloying material from outside the region. It is clear that at Saruq al-Hadid, similarly to other Early Iron Age sites in Southeastern Arabia (Goy 2019), a wide range of tin concentrations was employed in the production of finished artefacts, no doubt in part a reflection of widespread recycling of copper-base artefacts. Lead isotope analysis indicate that a large proportion of the analysed ingots, production debris, and finished and semi-finished artefacts derived from copper sources from the Semail Ophiolite in Oman. However, several outliers suggest the import of particular copper-base artefacts or raw materials.

The evidence of 'scrap' copper-base metal pieces from Area F/G (Weeks *et al.* 2017: Fig. 20), usually identified by the fact that they are broken and/or folded, and the inclusion of finished artefacts alongside raw metal in a vessel from Area 2A (Valente *et al.* 2020: Fig. 10), indicates that the recycling of metal was a common practice at the site. This evidence matches the compositional data from the wider region indicating the prevalence of recycling in Early Iron Age metallurgy in Southeastern Arabia (Goy 2019), as well as ancient written sources from Mesopotamia in which the recycling of metal is repeatedly mentioned (e.g. Moorey 1994: 254).

In exploring the nature of copper-base artefact production at Saruq al-Hadid, it must be acknowledged that some (perhaps a considerable proportion) of the excavated artefacts were imported to the site as finished artefacts, perhaps even from outside Southeastern Arabia. Despite typological parallels to copper-base artefacts from the UAE and Oman (e.g. 'Uqdat al-Bakrah, Jabal Mudhmar, Adam, Daba, Ibri, Masafi, Salut), many of the most elaborate artefacts from the site, including for example the bimetallic bronze-iron daggers with strong Iranian parallels (Weeks and Petrie, in press), or braziers with bulls' hooves with parallels in Urartu (Potts 2009), are candidates for such imports. Such artefacts remain largely unstudied in archaeometric terms.

Copper and ritual deposition at Saruq al-Hadid

The contexts in which copper-base artefacts and residues were recovered at Saruq al-Hadid encourage their interpretation as not simply the remains of mundane craft activities, but as the material manifestation of ritual activities of considerable social and/or political significance. As Hull (2014: 165) has stated: "... all ancient societies lacking writing systems probably depended upon ritual – and especially the performative aspects of ritual — as one means within a relatively limited repertoire of media through which values, meaning and identity could be created, expressed, reinforced and negotiated." Budd

and Taylor (1995: 139) likewise highlight the importance of ritual for ancient metallurgical practice in non-literate societies, where complex procedures might be committed to memory as 'spells'.

As described in detail elsewhere (Valente *et al.* 2020; Weeks *et al.* 2019b), ritual activities at Saruq al-Hadid include the careful placement of raw copper (including ingots and amorphous lumps) alongside arrowheads, axe heads, daggers, swords, jewellery (bead necklaces, earrings, rings and bracelets) and copper-base snake figurines. Next to these agglomerations, the presence of alabaster, soft stone and ceramic ware (snake-decorated, Grey Ware and spouted vessels) is also common. Miniaturised weaponry, such as axe heads and daggers, is also a component of several of these ritual deposits, including near a group in Area 2A that included multiple anthropomorphic and snake figurines (Valente *et al.* 2019). The constellations of materials deposited at Saruq al-Hadid demonstrate ritual activities characterised by a complex intersection of symbols and beliefs and likely cross-cutting any simple division between sacred and profane. This complexity is now beginning to emerge at a regional scale, as witnessed in a variety of manifestations at cultic sites across Early Iron Age Southeastern Arabia (e.g. Benoist *et al.* 2015), which seem to have been a fundamental aspect of the reproduction of Iron Age society.

To better understand the 'ritualisation' of copper production and deposition at Saruq al-Hadid, it is necessary to explore the co-mingling of artefacts of different materials, functions and provenance at the site. As noted above, ritualised deposits appear either in the shape of small agglomerations in Area F/G, in between sterile deposits, or in successive, concentrated accumulations as observed in Area 2A. In addition to their different intensities and/or periodicities of deposition, however, Areas F/G and 2A also display some differences in the types of objects incorporated into ritual activities, which seem to reflect different types of rituals.

In Area F/G (Figure 11), we observe mostly copper-base weaponry dispersed through small, ritualised deposits, which also include copper-base snakes and 'incense' burners in both copper and pottery, many snake-decorated (Karacic *et al.* 2017). Alongside these materials, the Area F/G assemblage is also characterised by the presence of alabaster, soft stone, iron and precious metal artefacts, finely crafted products in shell and bone, and pottery vessels (the majority in bowl form). Although these deposits are among the richest and most varied examples of their kind from the wider region, they nevertheless compare closely with deposits found at several other Early Iron Age sites in Southeastern Arabia, including Bithnah (Benoist 2005; 2007; Benoist *et al.* 2012), Masafi (Benoist *et al.* 2015), the 'mound of serpents' at Al Qusais (Taha 2009), Jabal Mudhmar (Gernez *et al.* 2017; Gernez and Jean 2020) and Salut (Avanzini and Degli Esposti 2018). Collectively, these sites document a region-wide tradition of cultic or ritual activities related to a 'snake deity'

Figures 11a and 11b: Some typical artefacts from ceremonial deposits in Area F/G (© Hélène David-Cuny, Anna Zuber, Edurne Fernández and Julia Coso)


JM 2592
SARUQ AL-HADID
GR 15380
GR 12216
GR 9625
GR 15358
SF 30880
SF 30701
SF 30705
SF 36265
SF 31814
SF 30707
SF 30703

(Mouton *et al.* 2011; Cian 2015; Karacic *et al.* 2017), with numerous examples of snake-decorated pottery and small copper-base figurines depicting this animal. The evidence for the burning of aromatics (probably incense) at each of these sites indicates its importance in cultic events in general.

Furthermore, it is clear that the by-products of metallurgical activity at Saruq al-Hadid were incorporated into these 'ritualised' deposits. The variety of copper-base metallurgical residues found in such contexts include small amorphous copper lumps, larger pieces of slag, raw copper 'ingots' and plano-convex ingots produced after refining. In both areas of Saruq al-Hadid, these are observed as small piles or collections of material placed with or next to other deposited materials. This practice parallels contemporary sites, for example Masafi and Bithnah (Benoist *et al.* 2015), where metallurgical residues including 'furnace bottoms' and ingots were also found inside pottery vessels decorated with snakes or in pits. Similar collections were also identified in Salut (Avanzini *et al.* 2007) and at 'Uqdat al-Bakrah, where a small number of snake figurines is known (Yule and Gernez 2018: cat. nos. 399, 400).

Together, this evidence supports the theory that such materials are votive offerings to propitiate a snake deity who is associated with metallurgical knowledge and production (Benoist 2010; Benoist *et al.* 2015). The symbolism of the snake as a transformative and creative force, intertwined with fire and the craft of metalworking, can be found in various cultures across different regions. In ancient Southwest Asia, the snake had multiple aspects and associations, including healing, water and fertility. As a symbol of renewal and regeneration, in several cultural traditions the snake represented the transformative powers involved in the creation and manipulation of metals (Rothenberg 1972; Miroschedji 1981; Bollhagen 1983; Golan 2003; Münnich 2008; Zych 2019).

Nevertheless, alongside the presence and significance of production residues and raw copper, the social importance of *finished* copper-base artefacts in these rituals must also be considered. At Saruq al-Hadid, the variety of such finished objects is extraordinary — from simple tools such as pins/needles, hooks and hoes to decorative items such as bracelets and rings, and vessels of different forms (e.g. Boraik Radwan 2018). However, by far the greatest proportion of the finished objects comprises weapons, including axes, daggers and especially arrowheads; many thousands of the latter have been recovered from the site. Elsewhere in Iron Age Southeastern Arabia, copper-based weaponry is particularly abundant in the cultic assemblages from Al Qusaism (Taha 2009) and Jabal Mudhmar (e.g. Gernez *et al.* 2017: 111).

Miniaturised versions of weapons (and occasionally other object categories) are also common at these sites. Saruq al-Hadid has produced miniature bows, quivers, arrows, daggers and axes, often made as skeuomorphs in copper-base or precious metal. At 'Uqdat al-Bakrah, miniature axes and daggers are recorded (Yule and Gernez 2018: cat. nos. 86-87, 223-226, 360-368),

and Jabal Mudhmar has a wide range of such objects, including miniature skeuomorphs of axes, arrows, arrowheads, bows and quivers (Gernez *et al.* 2017; Gernez and Jean 2020). Each of these sites is known, moreover, for the presence of unfinished castings of copper-base weapons. These include both full-sized and miniature examples of socketed axe heads still with attached casting cup/sprues and flashing (e.g. Gernez *et al.* 2017; Yule and Gernez 2018: cat. nos. 82, 111-114).

The prevalence of weaponry in cultic contexts is undoubtedly of cultural significance, although identifying the specific nature and meaning of this practice for Early Iron Age societies in Southeastern Arabia is very challenging. At Jabal Mudhmar, the abundance of weaponry (especially archery-related artefacts) in votive contexts has been tentatively linked to their offering to a "warrior deity... as key elements of specific social practices" (Gernez *et al.* 2017: 111). Beyond the religious realm, one can consider the possibility that the deposition of weaponry to a deity with a martial aspect mirrored the existence of a 'warrior' ideology in contemporary society. Cross-culturally, such practices and beliefs have been linked to the emergence of warrior leaders or chieftains, who manipulated the materialised ideology of warriorhood to gain and maintain power, often through the control of relevant natural resources and/or industries, such as metallurgical production, and the exchange of these products and others considered 'prestigious' (Earle 1997).

Other material categories from cultic sites/deposits emphasise this aspect. In particular, the presence at Saruq al-Hadid of iron swords (in Area F/G only) alongside numerous bimetallic daggers (Boraik Radwan 2018: 48-53) is significant, as is the presence of rare examples of bimetallic artefacts in votive contexts at other sites, including Jabal Mudhmar, Al Qusais and 'Uqdat al-Bakrah (Stepanov *et al.* 2020; Weeks and Petrie, in press). Noting that there is no evidence of local iron smelting at any Iron Age site in the region, as well as the strong typological, technological and compositional parallels with contemporary material from Iran (Stepanov *et al.* 2020), it is highly likely that such artefacts were obtained through long-distance trading circuits. These votives are, therefore, profound exemplars of exotic and rare raw materials and craft skills. Not only symbols of a warrior identity, these weapons were also material manifestations of the power to participate in and control the long-distance movement of exotic materials, likely the prerogative of a highly circumscribed, elite segment of society, as proposed above. In Area F/G, their deposition simultaneously served purposes both sacred and profane: propitiating a deity that was responsible for knowledge of fire and metallurgy, while also demonstrating and legitimising the power of Iron Age community leaders.

To better understand this complex dynamic of belief, politics and economics, however, we must also consider the assemblage found in Area 2A which, as noted above, is somewhat different from the one identified in Area F/G. The

Figure 12: Some typical artefacts from ceremonial deposits in Area 2A. (© Anna Zuber, Edurne Fernández and Julia Coso)

assemblage from the ritual contexts in Area 2A (Figure 12) also contains offerings of copper-base snakes, weapons (miniaturised and regular), raw copper, and jewellery as described above. But, unlike Area F/G, incense burners have not been found there. As these seem to be a fundamental and pervasive component of cultic rituals at Iron Age sites in Southeastern Arabia, their absence in Area 2A suggests that more mundane 'political ceremonies', in the shape of gift exchange and convivial festivity (Benoist 2010), characterised activities in this area of Saruq al-Hadid. Although votive offerings to a snake deity were still a component of the material remains from Area 2A, here only agreements and exchanges between those who visited the site seem to have been celebrated. Similar actions have been observed in other societies, where celebrations and ceremonies reinforced and legitimised ties between individuals and groups, providing recognition of authority, legitimacy and mutual obligations, particularly between actors at threat of conflict or simply between political entities within the same region, who relied on each other economically or politically (Levy 1995; Swenson 2015; Swenson and Berquist 2022).

The ceramic assemblage found in Area 2A adds to our consideration of this hypothesis. Area 2A is dominated by Grey Ware jars and spouted vessels (Benoist and Valente 2017) which parallel examples found in Rumeilah, Dadna, Bithnah, Wadi Al Qawr, and Muweilah (Benoist 1999; Benoist and Ali Hassan 2010; Corboud *et al.* 1996; Phillips 1987; Magee 1998a; Benoist and Méry 2012). As likely products of the extra-regional exchange circuits noted above, these vessels also had an enhanced material significance. Such vessels are comparatively rare in Area F/G, which is instead dominated by Sandy Ware bowls and snake-decorated vessels of local production (Karacic *et al.* 2017). Steatite and copper vessels (many spouted), although produced locally (David 2002), also occur frequently in the Saruq al-Hadid assemblage and parallel those of Iron Age contexts in the region (Lombard 1985; Ziolkowski 2001; Genchi and Tursi 2022; Taha 1981; Valente *et al.* 2023). Finally, the presence of ladles is also attested on-site, paralleling those found at Muweilah (Magee 1998a). Collectively, such objects suggest a pervasive commensality at Saruq al-Hadid; in this respect, they resemble the assemblages found in meeting and administrative buildings across the region, including the columned halls of Muweilah (Magee 2002; 2007), Bida bint Saud (al-Tikriti 2002) and Rumeilah (Boucharlat and Lombard 2001), for example.

Together, this evidence suggests that activities in Area 2A, while redolent with cultic imagery and characterised by the performance of offerings, took place within a context where people would banquet and celebrate. This celebration likely encompassed not only the craft production undertaken there, but also the gathering itself and the social connections that came from it.

Copper and the 'ritual economy' of Early Iron Age Southeastern Arabia

Above, we have argued that copper technology was 'ritualised' at Saruq al-Hadid, as manifested through votive offerings to a snake deity who controlled metallurgical knowledge and production, and who was venerated by the deposition of metal production residues and finished artefacts, especially weapons. However, it can be argued that ritualization characterises not only the technology of copper production at Saruq al-Hadid, but also its economic organization.

Over the last two decades, archaeologists have worked to break down the pervasive, Western, dualistic conception of a (rational) sphere of economic action that can be contrasted with an (irrational) sphere of ritual action, in particular by deploying the concept of the 'ritual economy'. Such an approach explores the ways in which rituals can structure craft practices and the production, distribution and consumption of craft goods (e.g. Miller 2015; McAnany and Wells 2008). Archaeological and ethnographic studies of ritual economies have highlighted, for example, societies in which the ritual cycle "structures production and consumption... in a manner outside of the political control of any one group or individual. In this case economic interactions became embedded in the ritual cycle as a means to ensure peace and reciprocity while uniting groups outside of the bonds of kinship" (Miller 2015: 125).

Although ritual economies have been explored as engines for the intensification of production in small scale, non-centralised societies (e.g. Miller 2015; Everhart and Ruby 2020), the mutually constitutive realms of ritual and economy nevertheless provide many opportunities for ritual production to be co-opted in the exercise of power and the negotiation of (uneven) social relationships. In a particularly relevant case study from the Late Moche site of Huaca Colorada in Peru, Swenson and Warner (2012) identify the gathering together at the site of people from spatially separated communities for the purposes of copper production — smelting, refining and object fabrication — that was associated with feasting and ritual activities. In their assessment, "copper metallurgy was intimately associated with ritual transformation complicit in the forging of political identities and dependencies" (Swenson and Warner 2012: 314). Critically, however, they note that the contexts in which metallurgical production was undertaken indicate that "participation in the metallurgical artisanry was not one of coercive or top-down subjugation. Instead, metallurgy, feasting, sacrifice, and the exchange of finished products... contributed to a sense of community integration and interdependency" (Swenson and Warner 2012: 315). Here, we argue that a perspective derived from the concept of ritual economies is valuable in understanding the organisation of copper production in Early Iron Age Southeastern Arabia and its specific materialization at sites such as Saruq al-Hadid.

Benoist (2010) has discussed authority and religion in the Southeastern Arabian Iron Age, correlating data from several cultic sites and meeting places. Her review highlights the evidence for cultic activities, gatherings and festivity, but also the close association and importance of these activities for the management and sharing of resources, in a way that aligns well with the workings of a ritual economy. Although numerous sites evidence either one or another aspect of authority and religion, Saruq al-Hadid's rich material assemblage, despite not yet providing any evidence for columned halls or cultic structures, shows it to be a place where members from communities across the region could gather for the purposes of craft production, and while doing so, enact religious, social and political events that were fundamental to social reproduction and cohesion, as well as the negotiation of relations of power and prestige. Here, the liminal desert locations of sites such as Saruq al-Hadid and 'Uqdat al-Bakrah (Yule and Gernez 2018) are not anomalous, but rather a key criterion of their function: They represent a space *for* many communities but not *of* any specific community and outside the control of any one group or individual. If we consider the Iron Age population of Southeastern Arabia as experiencing an increased likelihood or threat of conflict — a suggestion supported by the fortification of many sites in the region during this period (e.g. Benoist 2010) and also the abundance of weaponry produced at this time — the need for places and rituals of social cohesion becomes clear.

If conflicts were occurring between the Iron Age communities of the region, or simply if every settlement had its own elite controlling and defending specific territories and resources, sites like Saruq al-Hadid and 'Uqdat al-Bakrah may have been crucial to formalise and consolidate extra-community ties, and a sense of interdependency, as well as the authority of the elites who gathered there periodically (e.g. see Swenson and Berquist 2022). Magee (1998a; 2002; 2007) has repeatedly stressed this idea and refers to the evidence supporting the existence of such elites. The referred characteristic assemblage found in columned halls – and at Saruq al-Hadid – comprises objects such as spouted vessels and ladles, which seem to symbolise the power of those who possess them. Similar claims can be made regarding the control of foreign resources such as iron (Magee 1998b) or tin for copper alloying (Weeks and Petrie, in press), or the Grey Ware vessels found at Saruq al-Hadid (Benoist and Valente 2017), noting that some could be local imitations. Many of these materials may be of Iranian origin or obtained via Iran (Weeks and Petrie, in press), suggesting economic connections between elites in these areas who were responsible for the control and distribution of such products. Furthermore, the production of decorated shells buttons and beads of various materials is also attested at the Saruq al-Hadid (Weeks *et al.* 2019c; Rempel *et al.* 2021), thus stressing the idea that many forms of 'prestigious' production took place at the site and were incorporated into its ritual economy. Trading evidence

found at Saruq al-Hadid also supports the idea of numerous groups of people coming together at the site to engage in exchange. This includes scale pans (Boraik Radwan 2018: 47), which indicate the weighing of items such as metal ingots, objects and scrap for exchange, as well as an extensive and diverse collection of stamp 'seals' found at the site (Karim *et al.* 2017). In fact, the entire paraphernalia observed in cultic and administrative or communal meeting structures in Iron Age Southeastern Arabia, always charged with ritualised symbolic practices, appears to have been produced, offered and exchanged at Saruq al-Hadid.

Conclusions

This study has summarised the evidence for copper production and use at Saruq al-Hadid, alongside other craft activities focused on elite or prestige good manufacture, and has outlined the details of an elaborate set of associated ritual practices directed towards a snake deity. It has been argued that this copper production – typically envisaged as a leading 'industrial' technology of its time that provided a major raw material for exchange – cannot be properly explored in purely technological and economic terms. As Budd and Taylor (1995: 138-139) suggested many years ago: "metal-making was a non-scientific business, highly varied and variable, in which the various activities for which we have archaeological evidence were carried on alongside social activities which we cannot easily infer. Those activities may be better described as 'ritual' or 'symbolic' rather than 'economic'." Here, we have argued that the production and deposition of copper at Saruq al-Hadid can only be properly understood within complex, culturally specific beliefs and practices, and with the recognition that aspects of a 'ritual economy' shaped the nature of the Iron Age copper industry in Southeastern Arabia.

Previously, Saruq al-Hadid has been conceptualised within the framework of 'Arabian pilgrimage' (Magee 2014: 239-240; Weeks *et al.* 2019b: 173), a social practice that has been described as "a constellation of gathering, sacrifice, and feasting at a sacred place to assemble and reify communities that are not coresident" (McCorriston 2013: 608). While this model maintains its fundamental interpretive relevance for understanding a site such as Saruq al-Hadid, its explanatory power is enhanced when broadened to include the insights of studies of ritual economy; specifically, that such gatherings mobilised, and were mobilised by, ritualised craft production of copper and other materials.

Much work remains to be completed on the metallurgical remains from Saruq al-Hadid. This includes, but is not limited to: a fuller catalogue of metal artefacts from the site; comprehensive archaeometric studies of metal extraction, composition, fabrication, use and provenance; and an exploration of interactions and technological transfers between the various high-temperature

crafts attested at the site. Critical to the success of these endeavours will be the continued parallel development of interpretive frameworks that capture the full complexity of the social contexts in which metallurgy developed in Early Iron Age Southeastern Arabia.

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