Beyond the major sites: rethinking small-scale copper production in ancient Oman. A preliminary report on the archaeometallurgical survey of the Salh site (Ad Dhahirah Governorate, northern Oman)

Abstract: The site of Salh 1, situated in the Ad Dhahirah Governorate of northern Oman, offers insights into the organization of copper production in southeastern Arabia. Preliminary results of archaeological and geoarchaeological investigations indicate that this smelting site, active during both the Bronze Age and the Islamic period, functioned as a small-scale production center. Surface surveys and test trenching enabled the estimation of the total volume of slag deposits at approximately 288 tons. The discovery of stone-built structures, tools for copper processing, and fragments of clay smelting furnaces all point to a systematically organized and continuously operated metallurgical process. In light of the absence of nearby domestic architecture, Salh 1 is interpreted as a small, seasonal metallurgical site. These findings contribute to the growing body of archaeometallurgical research in Oman and highlight the significant, yet often overlooked, role of smaller smelting sites in shaping the region's economic landscape during key periods of copper production.

Keywords: Arabian Gulf archaeology, Oman, Bronze Age, Islamic period, metallurgy

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INTRODUCTION

As early as the early 20th century, scholars observed that advances in the smelting and working of metal were inextricably linked to broader processes of social change. Within archaeology, a high degree of craft specialization —metalworking above all— has long been viewed as one of the most sensitive indicators of sociopolitical complexity (Childe 1936; 1950). From this perspective, Oman offers a particularly valuable area of research. Its rich copper deposits, situated at the crossroads of ancient trade routes, allow for a comprehensive analysis of the entire production sequence, from ore extraction to metal distribution. Unsurprisingly, the region's early metallurgical record has been the subject of intensive investigation since the late 1970s. However, previous research on ancient copper smelting in Oman has predominantly focused on large and well-preserved production centers (Costa 1978; Weisgerber 1980; 1987; Hauptmann and Weisgerber 1981; Giardino 2019; Sivitskis et al. 2019; Hauptmann 2020).

This article presents the preliminary results of archaeological and geological surface surveys conducted at the Salh 1 site in northwestern Oman. As a smaller, specialized smelting site situated on the periphery of major industrial complexes, Salh 1 offers valuable insights into more decentralized, flexible, and potentially seasonal production systems. Evidence of metallurgical activity —including accumulations of slag, stone tools, and fragments of ceramic furnaces— has been recorded, allowing for analysis of both technological organization and local economic significance.

The chronological framework of the site is based on the analysis of samples collected directly from the site. These indicate two main phases of activity: the mid-3rd millennium BCE and the 5th century CE. Both periods align with well-documented phases of intensified copper production in the region, corresponding to the Early Bronze Age and the early Islamic period, respectively. These peaks in activity were driven by expanding trade networks and periods of political stability (Begemann et al. 2010; Steinkeller 2013; Laursen and Steinkeller 2017; Giardino 2019; Zaribaf et al. 2024).

The fieldwork, conducted by the Omani–Polish Archaeological Mission (PCMA UW), aimed to assess the scale of metallurgical activity through slag volume analysis and to evaluate the significance of the site within the framework of the local economic system.

RESEARCH AREA

The Salh site is located in the al-Ẓāhira (Ad Dhahirah) Governorate, approximately 24 km southeast of the town of Dank [*Fig. 1:A*]. The study area encompasses two closely situated sites, Salh 1 and Salh 2 [*Fig. 1:B*]. Archaeological fieldwork at both locations was conducted by the Omani–Polish Archaeological Mission (PCMA UW) as part of a broader initiative to investigate early copper production in northwestern Oman.

This article focuses primarily on Salh 1, which extends along a valley at the junction of a broad alluvial fan and a high gravel terrace of Wadi al-Salh, covering an area approximately 300 m long and 60–70 m wide. Surface surveys revealed a layer of slag, stone tools associated with ore processing, and numerous fragments of metallurgical furnaces. Additionally, 27 stone structures of varying forms and degrees of preservation were identified (Bieliński 2023). Approximately 200 m southwest of Salh 1, on a higher terrace level, a second site, Salh 2, was documented. Within an area of about one hectare (100 m × 100 m), six semicircular stone structures were recorded. In contrast to Salh 1, there is no clear evidence of metallurgical activity at Salh 2 — no tools, furnace fragments, or significant quantities of slag were found, apart from a few isolated pieces (Bieliński 2023).

SALH 1

A slag layer covering approximately 80% of the surface area at Salh 1 constitutes one of the most prominent indicators of intensive metallurgical activity at the site. Two primary slag concentrations were identified, forming small elevations that subtly shape the terrace landscape. The first concentration, located in the southeastern sector and referred to as Area I, comprises three discrete subzones: IA, IB, and IC, with respective diameters of 14 m, 7.5 m, and 12.6 m. The second concentration, situated in the northern part of the site, spans an area of approximately 33 m × 20 m (Area II) [*Fig. 2:A*]. To estimate the total volume of slag, four test trenches (1 m × 0.5 m) were excavated in both high-density slag zones and areas of lower activity [*Fig. 3:A, B*]. Excavation was conducted in 5 cm thick mechanical stratigraphic layers down to the sterile subsoil. The recorded slag thickness was

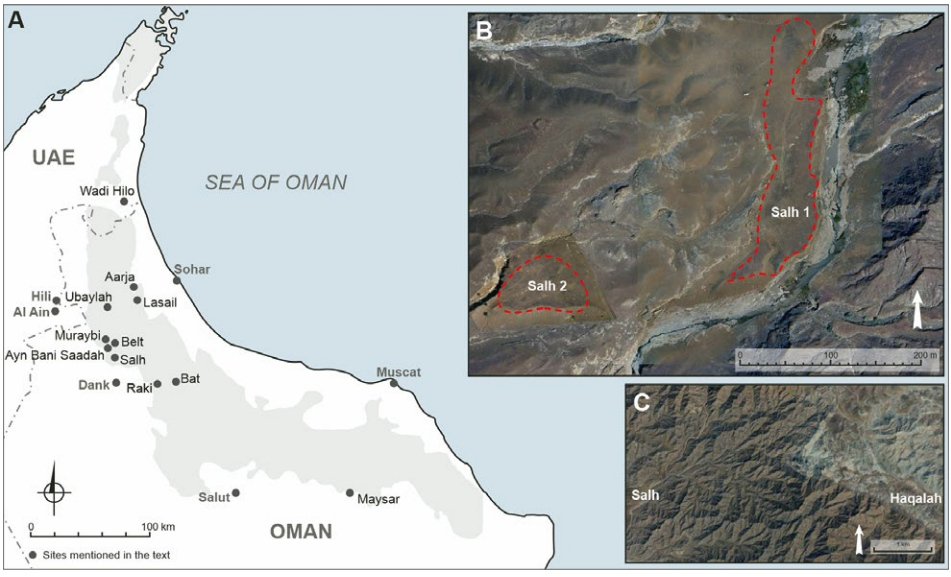

Fig. 1. a – Location; b – site plan of Salh 1 and Salh 2; c – Haqalah (Digitization M. Momot)

0.25 m in Areas IC and IIA, 0.40 m in Area IB, and 0.45 m in Area IA (Bieliński 2023; Bukowski et al. 2025).

Based on the weight of slag recovered during test trenching and the surface area of each subzone, average slag density was

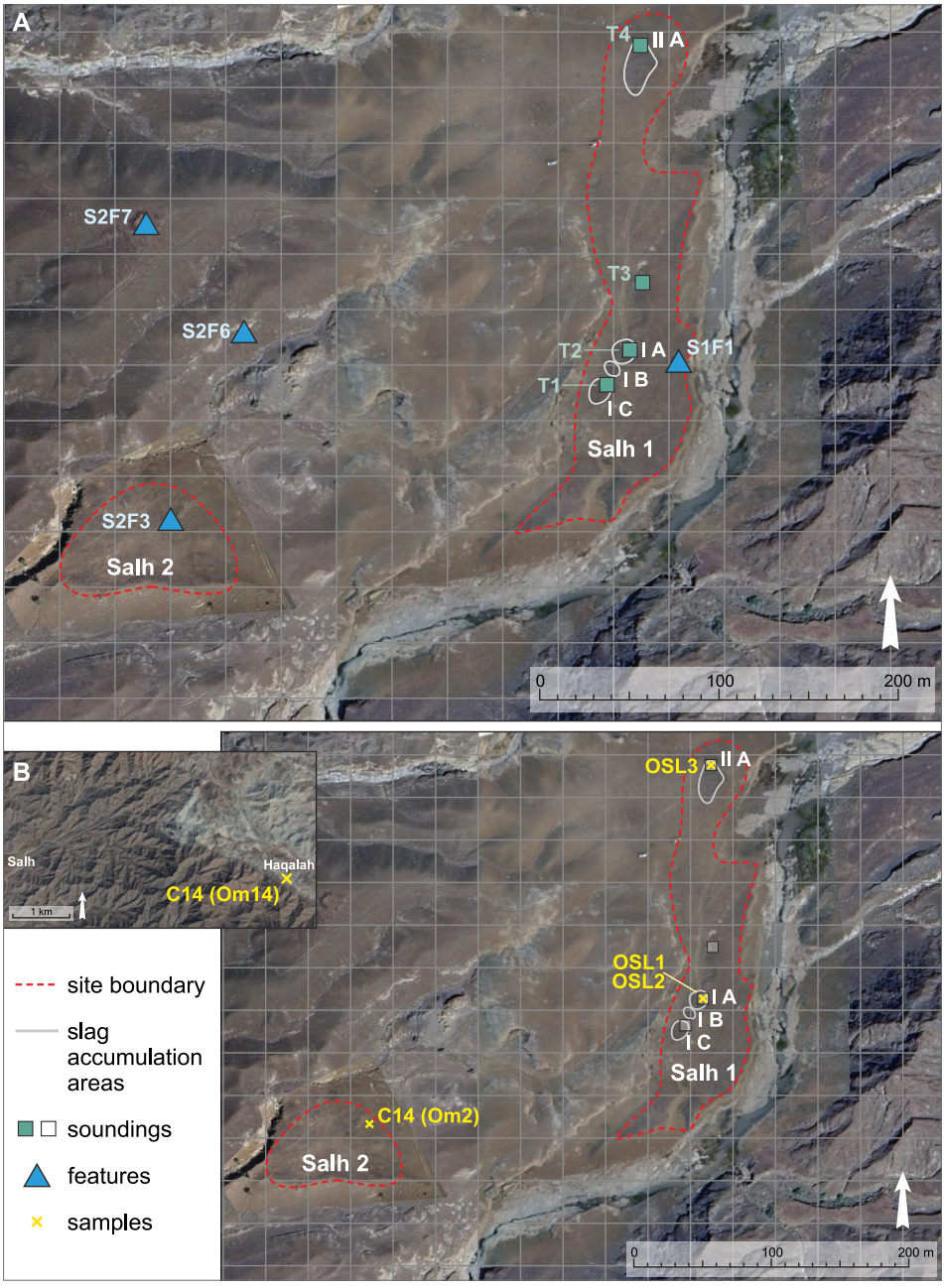

Fig. 2. a – Plan of Salh 1 and Salh 2; b – sample collection points at the sites (Digitization M. Momot)

calculated as follows: IA – 356 kg/m²; IB – 334 kg/m²; IC – 239 kg/m²; IIA – 66.5 kg/m². These values correspond to an estimated total of approximately 105 metric tons of slag in the sampled zones. Projections based on slag layer thickness in the remaining parts of the site indicate an additional 183 tons. Altogether, the total volume of slag deposited at Salh 1 is estimated at approximately 288 metric tons (Bukowski et al. 2025).

This volume situates Salh 1 within the category of small-scale production centers —smaller than major metallurgical sites such as Lasail, Raqi, or Arja— yet clearly indicative of well-organized and sustained smelting activity (Costa 1978; Weisgerber 1987).

A total of 27 stone-built structures were identified at the Salh 1 site [*Fig. 4*]. The most noteworthy feature is structure S1F1, which represents the best-preserved and largest building within the site [*Fig. 5*]. Located on the eastern edge of the wadi terrace, close to Areas IA–IC, the structure measures approximately 10 meters in length. It consists of two rectangular rooms with approximate dimensions of 5 m × 2.5 m and a semi-circular annex attached to the eastern side. The walls, approximately 70 cm thick, were constructed using dry-stone masonry techniques and consisted of two parallel rows of large, rounded boulders, with the space between them filled with smaller local gravel and no mortar.

Fig. 3. a, b – Test trenches; c – different types of stone tools (Photos A. Pieńkowska, O. Puszkarewicz; digitization A. Pieńkowska)

Test trenches excavated within the structure revealed that the walls are preserved to a height of approximately 30 cm [*Fig. 5:B*]. No occupational floor levels or *in situ* cultural layers were identified inside the rooms, likely due to erosion or secondary disturbance. Given the limited surface and subsurface data, the function of the structure cannot be confidently determined. Its architectural configuration and setting exhibit features reminiscent of a metallurgical workshop, although this interpretation remains provisional. This suggestion derives in part from similarities to Workshop Area F at the HLO1 site in Oman — a multi-room dry-stone complex with semicircular additions and stratified metallurgical debris interpreted as a Bronze- to Iron-Age industrial installation (Kutterer and Jasim 2009; Kutterer 2013; Kutterer, Neureiter, and Jasim 2013). Nevertheless, the parallel is imperfect, and in the absence of artifacts or stratigraphic evidence the analogy must be regarded as tentative.

In contrast to S1F1, the remains of architectural features identified at Salh 1 are markedly more fragmentary and poorly preserved. In most cases, only isolated wall segments survive, generally erected using the same dry-stone technique documented in S1F1. The surface-visible wall traces exhibit both rectilinear and curvilinear alignments. Based on the available surface-survey data and the current state of preservation, it is impossible to reconstruct their original layout, spatial organization, or intended func-

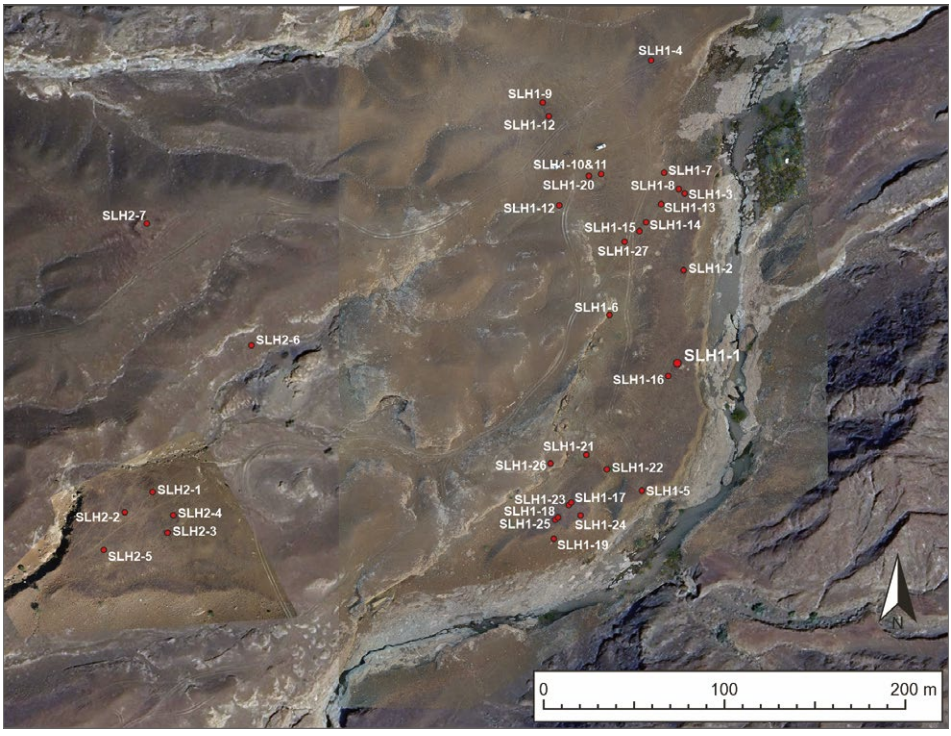

Fig. 4. Stone structures at Salh 1 and Salh 2 (Digitization P. Czernic and M. Momot)

tion. Given the fragmentary nature of the evidence, the results of the surface investigations do not allow for any conclusive interpretations.

SALH 2

At the Salh 2 site, several architectural features were identified, characterized by curved, semi-circular wall constructions [*Fig. 6*]. The best-preserved among them —structure S2F3—consists of a semi-circular wall approximately 70 cm thick, forming a semicircle with an estimated diameter of about 5 m. This wall displays a notably higher degree of regularity compared to structure S1F1 at Salh 1. It was constructed using two parallel rows of medium-sized stones, with the intervening space filled with smaller pebbles and rubble. The construction technique suggests a more deliberate, possibly later building phase, and may reflect a different architectural approach or functional requirement than that observed at Salh 1. Similar semi-circular structures have also been identified further north of Salh 2, indicating that this architectural form may have been more widespread in the region than previously recognized.

MATERIAL AND TECHNOLOGICAL EVIDENCE

Fig. 5. Structure S1F1 (Photo S. Lenarczyk; digitization M. Momot)

ARTIFACTS AND OPERATIONAL SEQUENCE

The predominant category of artifacts recovered at Salh 1 comprises stone tools used in the processing of copper ore [*Fig. 3:C*]. Frequently encountered examples include pitted crushing stones and anvils, typically made of hard rocks such as gabbro. These tools often show visible signs of intensive and prolonged use, including battered edges, pitting, and impact marks indicating repeated crushing and striking of ore. A particularly characteristic group includes small cuboid stones with wear traces on several —and sometimes all— faces. Such patterns suggest the use of these tools in multidirectional ore crushing, a key activity in the early stages of ore treatment. Anvils, identified by shallow impact depressions, likely served as stable working surfaces for crushing and fragmenting ore.

Comparable tools have been recorded at other smelting sites across southeast-

ern Arabia, reflecting a long-standing and widespread technological practice from the Bronze Age to the Islamic period. Unfortunately, these tools offer limited chronological resolution due to their simple and conservative forms and long-term persistence. This enduring morphological consistency underscores both their practical efficiency and their central role in the operational sequence (*chaîne opératoire*) of copper metallurgy in the region (Weisgerber 1978).

In addition to stone tools, a significant category of finds consists of ceramic fragments of copper-smelting furnaces. A distinctive feature of these fragments is the presence of a vitrified layer on their interior surfaces, formed at high temperatures during metallurgical processes. Furnace fragments are primarily concentrated within two zones characterized by the highest slag accumulation —Area I and Area II— while the stone tools are located in their immediate vicinity [*Fig. 7*].

A reconstruction of the metallurgical production sequence, based on tool analysis and contextual evidence, suggests that the process likely began with the crushing and cleaning of copper ore using hammerstones and anvils, followed by roasting the ore in small clay furnaces. The largest concentrations of furnace fragments are located in areas with the highest slag accumulation, suggesting that furnaces may have been situated in these zones. Moreover, the highest density of stone tools was recorded in the central part of the site, indicating that this area may have served as a key locus of ore-processing activity during the early stages of copper metallurgy.

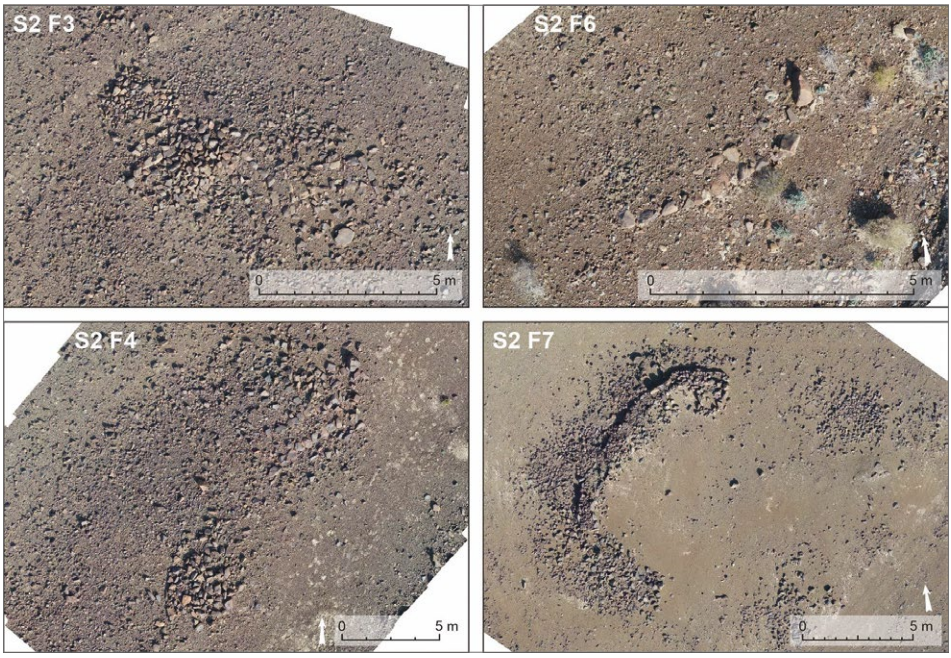

Fig. 6. Stone structure at Salh 2 (Photo S. Lenarczyk; digitization M. Momot)

CHRONOLOGY

The chronology of the Salh 1 site has been established through a combination of optically stimulated luminescence (OSL) and radiocarbon (^{14}C) dating. Three OSL samples [*Fig. 2:B*] were collected from slag heaps and furnace fragments within Areas I and II (Bukowski et al. 2025: Table S3). These results indicate that Salh 1 experienced two main phases of metallurgical activity: the first during the Early Bronze Age and the second during the early Islamic period. The radiocarbon dates from Salh 2 (sample Om 2; see [*Fig. 2:B*]) point exclusively to metallurgical activity during the later Islamic period (Bukowski et al. 2025: Fig. S4). However, this chronological framework remains provisional: the relatively small number of OSL and radiocarbon samples precludes firm conclusions, and additional analyses will be needed before more than a tentative phasing of the site's occupation can be proposed (Bukowski et al. 2025).

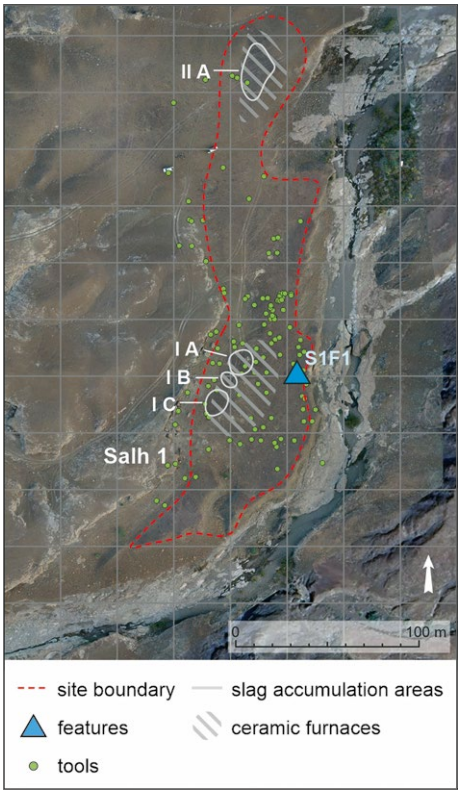

Fig. 7. Map of Salh 1 (Digitization M. Momot)

COPPER ORE PROVENANCE

The origin of the copper ore processed at Salh 1 has not been definitively determined. No outcrops of copper ore —typically indicated by the presence of minerals with green or blue coloration— were identified in the immediate vicinity of the smelting site. The area mainly comprises ultramafic rocks, such as peridotites, with low average copper content (Bukowski et al. 2025).

Field studies have shown that the nearest known occurrences of copper ores, including malachite, azurite, and atacamite, are located near the village of Haqalah, approximately 4 km east of Salh 1 [*Fig. 1:C*]. In this area, evidence of historical mining activity has been recorded, including adits, a small quarry, the remains of smelting installations, and slag deposits (Bieliński 2023). Preliminary radiocarbon data suggest that the metallurgical remains from Haqalah date to the late Islamic period (sample Om 14; see *Fig. 2:B*), whereas activity at the Salh 2 site corresponds to an earlier phase of the same period (sample Om 2). Although the two sites were not in use simultaneously, their geographical proximity allows for the hypothesis that the wadi may have served as a transport route for copper ore, albeit not necessarily during the same phase of exploitation. It should be noted, however, that the chronology of

both sites is based on only two radiocarbon dates, allowing for merely tentative interpretations and highlighting the need for additional data to refine and confirm the proposed chronological framework (Bukowski and Kiersnowski 2023).

DISCUSSION

The Salh 1 site is situated on a flat wadi terrace with immediate access to essential natural resources, including seasonal water flow and dense vegetation suitable for firewood collection. These conditions created a highly favorable setting for metallurgical activity. The presence of water and associated plant life would have made fuel acquisition particularly accessible, especially considering the small scale of the smelting operations observed. Furthermore, palaeoclimatic studies suggest a more humid environment during the Bronze Age, which would have further enhanced vegetation density and resource availability in the region, facilitating metallurgical practices at the site. Environmental factors such as these likely played a decisive role in both the initial selection and continued use of Salh 1 as a copper smelting site (Proctor, Döpper, and Schmidt 2024). Salh 1 thus fits within a broader regional pattern observed across southeastern Arabia, where proximity to key natural resources largely determined the siting and longevity of metallurgical installations over millennia (Weisgerber 2007; 2020). The two occupation phases —the Early Bronze Age and the early Islamic period— correspond to periods of increased demand for copper, closely linked to expanding trade networks and regional socio-political stability. Nevertheless, the specific rationale for choosing Salh 1 as a smelting location remains unclear. One possible explanation —although currently hypothetical— is the proximity of a yet-unidentified settlement that may have been inhabited by a specialized group of miners or metalworkers, who could have organized production at the site due to its environmental, logistical, or social advantages. Alternatively, it is plausible that an as-yet unidentified ore deposit existed in the immediate vicinity, closer than the known sources around Haqalah (Bukowski et al. 2025: Fig. S5).

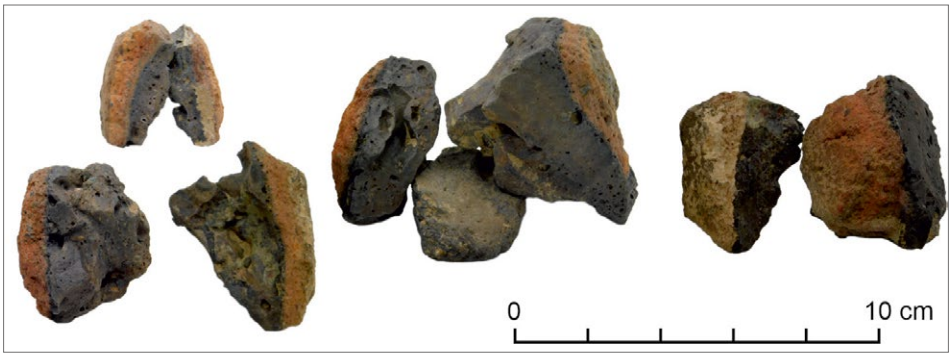

Fig. 8. Ceramic furnace fragments from Salh 1 (Photo H. Kiersnowski; digitization M. Momot)

The poor state of preservation of most structures at Salh 1, combined with the fact that investigations to date have been limited to surface surveys, prevents a reliable reconstruction of their original layout and function. Nonetheless, analogous semicircular and rectangular buildings at Wadi Hilo, located in direct association with furnaces and slag heaps, have been definitively identified as metallurgical workshops (Kutterer 2013).

Although architectural remains at Salh 1 are fragmentary, the spatial distribution of features across the site suggests a degree of functional zoning. Furnace wall fragments are concentrated near the densest slag accumulations in Areas I and II, both located along the site's periphery [*Fig. 8*]. In contrast, the presumed workshop (S1F1) and stone tools such as hammerstones and anvils are predominantly located in the central zone. This spatial configuration may reflect a deliberate division of labor, with ore processing activities concentrated in the center and smelting taking place on the margins of the site. Such functional differentiation may be interpreted as an indication of efforts to optimize metallurgical efficiency or as a possible sign of specialized labor within the production community.

When considered in conjunction with the nearby site of Salh 2, the spatial organization at Salh 1 gains further interpretive significance. The absence of stone tools, furnace fragments, and significant slag accumulations at Salh 2 suggests that this nearby location served a different purpose. It may have functioned as a residential or logistical support area used seasonally or for secondary ore processing. This spatial relationship between the two sites may indicate the existence of a micro-regional economic system characterized by functional differentiation between metallurgical production and ancillary activities. However, current archaeological data are insufficient to confirm the presence of such an organized spatial structure. The chronology of architectural remains at Salh 2 is also unclear. While a few ceramic fragments found there may date to the Islamic period, the lack of diagnostic pieces precludes definitive dating (Sobczak 2023).

Another key challenge concerns the estimation of production scale across different occupational phases, as well as the precise identification of which areas were in use during specific periods. Interpretation is hampered by the lack of ceramic material that can be securely attributed to a specific period. This challenge is further compounded by the near-total typological uniformity of the stone tools —primarily hammerstones, crushing stones, and anvils— whose simple and conservative forms hinder accurate dating. Comparable implements have been recorded at sites spanning several millennia, from the 3rd millennium BCE (e.g. Maysar 1; Weisgerber 1978), through the Iron Age (Goy et al. 2013), and into the Islamic period (e.g. Samdah and Tawi 'Arja; Weisgerber 1980; Hauptmann 2020).

In light of these interpretive challenges, insights from better-documented copper production sites across Oman can help frame possible organizational models for understanding the function and scale of Salh 1. Archaeological studies of Bronze Age copper production in Oman have identified two principal organizational models. The first in-

volves furnaces situated near or within domestic compounds, reflecting a high degree of economic and spatial integration between metallurgical practices and everyday domestic life (Weisgerber 1980; Hauptmann 1985; Weeks 2003). A well-documented example of this model is the Maysar 1 site, where metalworking debris was found within residential units. This configuration aligns with what Costin (1991) described as "community-based production", a system in which autonomous households collectively produce goods for wider regional exchange.

The second model is represented by large-scale, specialized production centers such as Tawi Ubaylah, which generated several thousand tons of slag and lacks evidence of domestic or administrative architecture. These sites likely operated under a different organizational logic, either as intermittently used hubs for mobile groups or as centrally managed facilities beyond the household level (Hauptmann 1985).

Salh 1 appears to diverge from both of these models in key respects. It is characterized by small-scale production, the absence of residential structures, and proximity to potential ore sources. These features may point to a decentralized, kinship-based system of seasonal smelting. Notably, the relatively modest slag volumes and limited infrastructure at the site should not be interpreted as indicators of low productivity. Instead, substantial output could have been achieved through short-term or cyclical operations aligned with subsistence strategies emphasizing local autonomy and self-sufficiency.

Viewed through this interpretive lens, Salh 1 may have served as a subsidiary or intermediary node within a broader and more heterogeneous landscape of metallurgical activity. It likely functioned as a localized production point while maintaining functional ties to larger regional systems of copper exploitation and exchange. This interpretation is further supported by the settlement pattern observed in the Qumayrah Valley, where Bronze Age sites such as Ayn Bani Sa'dah, Belt, and Muraybi have been documented (Bieliński et al. 2023). These sites occupy strategic positions along routes connecting the Omani interior with coastal trade zones (Frenez 2019; Eddisford 2022). It is therefore plausible that copper processed at Salh 1 —possibly in the form of semi-finished goods— was transported and exchanged through these broader networks.

The later phase of metallurgical activity at Salh 1, provisionally dated to the early Islamic period, may be situated within a broader regional transformation in copper production systems observed across northern Oman. Comparative evidence from major industrial centers such as Wādī al-Rākī and Tawi 'Arja suggests that early Islamic metallurgy operated within well-defined socio-political and legal frameworks, particularly under the Ibāḍī imamate (Zaribaf et al. 2024). These sites were sustained through regulated labor systems, concession-based access to resources, and formalized exchange networks, especially via coastal hubs like Sohar. Although Salh 1 lacks the massive slag heaps and monumental infrastructure typical of these centers, its location suggests that it may have functioned as a seasonal extraction point or logistical satellite within a larger metallurgical network, similar to the smelting site at Haqalah.

CONCLUSIONS

The case of Salh 1 highlights the diversity of copper production systems in southeastern Arabia, demonstrating that even modest sites could have played a role within complex regional networks. Although Salh 1 lacks extensive built features, its spatial organization and strategic location suggest integration into broader patterns of resource exploitation and exchange.

This study has shown that even smaller sites can offer meaningful insights into ancient metallurgical systems in Arabia. Salh 1 likely formed part of a broader, micro-regional economic network active during both the Bronze Age and the early Islamic period, operating in functional association with trade routes and settlements in the Qumayrah Valley. Its spatial organization, distinguishing processing from smelting zones, may reflect intentional labor structuring and task specialization.

However, several limitations restrict definitive interpretation. Chronological resolution remains tentative due to the lack of diagnostic material, and architectural remains are too poorly preserved to allow confident functional attribution. These uncertainties highlight the need for further excavation and detailed stratigraphic analysis to validate preliminary hypotheses.

Ultimately, Salh 1 illustrates the significance of smaller metallurgical nodes within broader systems of copper production in southeastern Arabia. A research focus limited to large, well-preserved sites risks obscuring the complexity of production landscapes. Incorporating sites like Salh 1 into regional models is essential for reconstructing a more nuanced, multi-scalar understanding of ancient technological and economic organization.

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References

Begemann, F., Hauptmann, A., Schmitt-Strecker, S., and Weisgerber, G. (2010). Lead isotope and chemical signature of copper from Oman and its occurrence in Mesopotamia and sites on the Arabian Gulf coast. Arabian Archaeology and Epigraphy, 21(2), 135–169

Bieliński, P. (2023). Omani–Polish Qumayrah Archaeological Project: The seventh season of field research in the area of Ayn Bani Sa'dah village—2023. Preliminary report. Unpubl. report for the Ministry of Heritage and Tourism, Sultanate of Oman, Muscat

Bieliński, P., Pieńkowska, A., Białowarczuk, M., Kiersnowski, H., Bukowski, K., and Lenarczyk, S. (2023). Patterns of pre-Islamic settlement in the Qumayrah microregion, northern Oman: First results of an archaeological and geological survey. Arabian Archaeology and Epigraphy, 34(S1), 22–38

Bukowski, K. and Kiersnowski, H. (2023). Sprawozdanie z geologicznych i geomorfologicznych badań terenowych w Omanie (Report on geological and geomorphological field studies in Oman). Unpubl. report for the Ministry of Heritage and Tourism, Sultanate of Oman, Muscat

Bukowski, K., Pieńkowska, A., Woronko, B., Moska, P., Kiersnowski, H., Piestrzyński, A., and Al-Ghafri, W.A.H.S. (2025). Archaeometallurgy in northern Oman: Diachronic copper production on a smelting site in Wadi al-Salh. Archaeometry, 67(6), 1692–1711

Childe, V.G. (1936). Man makes himself. London: Watts & Co.

Childe, V.G. (1950). The urban revolution. The Town Planning Review, 21(1), 3–17

Costa, P.M. (1978). The copper mining settlement of 'Arja: A preliminary survey. Journal of Oman Studies, 4, 9–14

Costin, C.L. (1991). Craft specialization: Issues in defining, documenting, and explaining the organization of production. Archaeological Method and Theory, 3, 1–56

Eddisford, D. (2022). Exchange networks of the Early Bronze Age Gulf: The imported ceramics from Kalba 4 (United Arab Emirates). Arabian Archaeology and Epigraphy, 33(1), 23–48

Frenez, D. (2019). Cross-cultural trade and socio-technical developments in the Oman Peninsula during the Bronze Age, ca. 3200 to 1600 BC. Ocnus, 27, 9–49

Giardino, C. (2019). Magan—The land of copper: Prehistoric metallurgy of Oman. Muscat: Ministry of Heritage and Culture, Sultanate of Oman

Goy, J., Le Carlier de Veslud, C., Esposti, M.D., and Attaelmanan, A.G. (2013). Archaeometallurgical survey in the area of Masafi (Fujairah, UAE): Preliminary data from an integrated programme of survey, excavation, and physicochemical analyses. Proceedings of the Seminar for Arabian Studies, 43, 127–145

Hauptmann, A. (1985). 5000 Jahre Kupfer in Oman I. Die Entwicklung der Kupfermetallurgie vom 3. Jahrtausend bis zur Neuzeit. Bochum: Deutsches Bergbau-Museum

Hauptmann, A. (2020). Archaeometallurgy—Materials science aspects. Cham: Springer

Hauptmann, A. and Weisgerber, G. (1981). Third millenium BC copper production in Oman. Revue d'Archéométrie, 1(1), 131–138

Kutterer, J. (2013). The archaeological site HLO-1: A Bronze Age copper mining and smelting site in the Emirate of Sharjah (UAE) (Ph.D. diss.). University of Tübingen. Retrieved from https://publikationen.uni-tuebingen.de/xmlui/handle/10900/56440 (accessed: 09.07.2025)

Kutterer, J. and Jasim, S.A. (2009). First report on the copper-smelting site HLO-1 in Wādī al-Ḥilo, UAE. Proceedings of the Seminar for Arabian Studies, 39, 245–253

Kutterer, J., Neureiter, C., and Jasim, S. (2013). Second report on the copper smelting site HLO1 in Wādī al-Ḥilo (Sharjah, UAE). Proceedings of the Seminar for Arabian Studies, 43, 185–196

Laursen, S. and Steinkeller, P. (2017). Babylonia, the Gulf Region, and the Indus: Archaeological and textual evidence for contact in the third and early second millennia B.C. Winona Lake, IN: Eisenbrauns

Proctor, L., Döpper, S., and Schmidt, C. (2024). Hafit period fuelwood preferences associated with early copper production at Building V, al-Khashbah, Oman. Proceedings of the Seminar for Arabian Studies, 53, 230–247

Sivitskis, A.J., Lehner, J.W., Harrower, M.J., Dumitru, I.A., Paulsen, P.E., Nathan, S., Viete, D.R., Al-Jabri, S., Helwing, B., Wiig, F., Moraetis, D., and Pracejus, B. (2019). Detecting and mapping slag heaps at ancient copper production sites in Oman. Remote Sensing, 11(24), 3014. https://doi.org/10.3390/rs11243014

Sobczak, M. (2023). Preliminary report on pottery from surface surveys in the Salh 1 and Salh 2 (Oman). Unpubl. report for the Ministry of Heritage and Tourism, Sultanate of Oman, Muscat

Steinkeller, P. (2013). Trade routes and commercial networks in the Persian Gulf during the third millennium BC. In C. Faizee (ed.), Collection of papers presented to the Third International Biennial Conference of the Persian Gulf (pp. 413–431). Tehran: Scientific Board of the Third International Conference of the Persian Gulf, Department of History, University of Tehran

Weeks, L.R. (2003). Early metallurgy of the Persian Gulf: Technology, trade, and the Bronze Age world. Boston: Brill

Weisgerber, G. (1980). Patterns of early Islamic metallurgy in Oman. Proceedings of the Seminar for Arabian Studies, 10, 115–126

Weisgerber, G. (1978). Evidence of ancient mining sites in Oman: a preliminary report. Journal of Oman Studies, 4, 15–28

Weisgerber, G. (1987). Archaeological evidence of copper exploitation at ʻArja. Journal of Oman Studies, 9, 145–172

Weisgerber, G. (2007). From green to red: Smelting red copper from the green ore. In S. Cleuziou and M. Tosi (eds), In the shadow of the ancestors: The prehistoric foundations of the early Arabian civilization in Oman (pp. 133–136). Muscat: Ministry of Heritage and Culture, Sultanate of Oman

Weisgerber, G. (2020). Copper from Magan for the Mesopotamian cities. In S. Cleuziou and M. Tosi (eds), In the shadow of the ancestors: The prehistoric

foundations of the early Arabian civilization in Oman (2nd ed., pp. 301–303). Muscat: Ministry of Heritage and Culture, Sultanate of Oman

Zaribaf, A., Lehner, J., Paulsen, P., Dumitru, I.A., Sivitskis, A., Arsenault, B., Fisher, B., Buffington, A., Dollarhide, E., and Harrower, M.J. (2024). Socio-political factors influencing early Islamic copper production in Oman. Proceedings of the Seminar for Arabian Studies, 53, 316–332