12 ICAANE

Proceedings of the 12th International Congress on the Archaeology of the Ancient Near East

Volume 1

Environmental Archaeology

Hammering the material world

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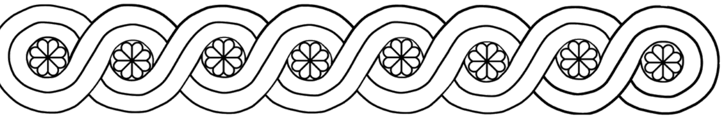

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The 12th ICAANE, Bologna: Foreword and Acknowledgments

Nicolò Marchetti

The defining event of the 12th ICAANE is, of course, that it has actually taken place, if not in a way that it could actually be foreseen. When the pandemic brought to strict lockdowns all over the world in March 2020, we were less than a month away from the Congress and this forced us to steer course through uncharted waters. That the 1033 initially registered participants were still 883 (of whom 64% regular and 36% students, plus *c*. 100 Middle Eastern officials) a year later within a totally different, remote formula is something to be credited to the trust as well as the sense of community of our colleagues and their determination to serve science and keep close mutual contacts alive despite all odds. 548 papers (including 192 of them distributed in 23 workshops) and 71 posters were presented in up to 15 parallel sessions: 142 papers about the main themes are published in these two volumes.

The Congress attempted at representing a multidisciplinary environment where to pursue interconnections (geographical and chronological as well) and inclusivity at all levels: just looking at the first authors, we have an almost perfect balance of women and men from 43 countries (Europe 68%, Asia 22%, North America 8% and Oceania 2%). Eight themes were selected in an attempt at representing the current breadth and urgency of global challenges and research perspectives: 1. Field Reports. Recent excavations, surveys and research; 2. Environmental Archaeology. Changing climate and exploitation strategies: impact on ecology, anthropized landscapes and material culture; 3. Hammering the material world. Characterization of material culture, processes and technologies; 4. Cognitive archaeology. Reading symbolic and visual communication networks and structures; 5. Modeling the past. Contemporary theoretical approaches to the archaeology of economies and societies; 6. Networked archaeology. Global challenges and collaborative research in the new millennium; 7. Endangered cultural heritage. Coordinated multilateral research, conservation and development strategies; 8. Islamic archaeology. Continuities and discontinuities between a deep past and modernity.

The trust that the ICAANE International Committee showed in 2018 towards the 12th ICAANE Organizing Committee of the Alma Mater Studiorum – University of Bologna about managing such a complex event must be acknowledged at the very onset. That the University of Bologna in the first place accepted to host an ICAANE was remarkable: the then Rector Francesco Ubertini is to be credited with unlimited enthusiasm for the idea and the Head of the Department of Legal Studies Michele Caianiello followed suit in ceding for a week to the Congress his most precious commodity, the perfectly functional Belmeloro lecturing complex, without which it would not have been possible to think to such an endeavour. The then Head of our Department of History and Cultures, Paolo Capuzzo, and our Department Administration were outstanding in showing at every corner flexibility and commitment as well as allocating resources for the Congress. We greatly benefitted from the experience and creativity in handling large scientific events of the FAM-Fondazione Alma Mater (and Alessandro Vriz, in particular, has been invaluable all throughout).

The ISMEO – Associazione Internazionale di Studi sul Mediterraneo e l'Oriente and its President Adriano Rossi allotted a grant for the Congress' organization and helped us assist and manage colleagues in Iran. The publishers Harrassowitz, Brill and Ante Quem supported the prize for the best poster by gifting books to the winners (C. Sadozai and S. Moriset "Post-excavation

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treatments of earthen archaeological sites"). Iperceramica and its CEO Corrado Neri assigned a prize in cash for the best paper on ancient tiles (M.-S. Zeßin "Marks on Glazed Bricks of the Neo-Assyrian Period from Ashur"), while the cash prize offered by Carpigiani remained unassigned. To all of them we are truly grateful for their generous support.

The Directors General of antiquities from Turkey, Iran, Iraq as well as KRG, Syria, Cyprus, Lebanon, Palestinian National Authority, Jordan, Saudi Arabia, Oman and Egypt accepted to present the policies and needs of their respective Countries about cultural heritage in a plenary session: this was a great honor and we are deeply grateful to them for their enduring trust and friendship. In the Opening Session, then students Giulia Piraccini, Margherita Robecchi, Roberto Santoro, Alice Zamarchi (coordinated by Ahmad Addous) performed a poetry reading in Arabic, Turkish, Farsi and English of the "Hymn of the Rain (Unshūdat al-Matar)," by Badr Shākir Al-Sayyāb. The musician Réda Zine played a memorable performance: "Reviewing the MENA musical heritage. Gwana music from Guembri to electric guitar." We are most grateful to all of them as well as to the colleagues who accepted to e-chair sessions, to the four keynote speakers selected only on the basis of the quality of their submitted papers (here published as the opening essays of themes 2, 3 and 1), to all the participants who have been almost invariably sympathetic towards our shortcomings and many requests to them and to the legions of anonymous referees for their hard work which enormously improved the contents of these Proceedings.

Bologna Welcome and ER.GO with its Director Patrizia Mondin were ready to host colleagues and students to the best of their considerable ability: that in the end they did not have a chance to fulfill that, does not subtract from their keen availability. The online infrastructure, Ibrida.io of Search On Media Group, offered us an immersive and seamless experience of a remote conference fully functional under every aspect: not only the professionalism of Vito Esposito and his vast team was appreciated by all participants, but their subsequent acceptance of our request to grant free access to (and thus to keep online) the recordings of all sessions for almost a year after the end of the Congress added an immense value to its dissemination and tore down economic barriers in accessing state-of-the-art scientific knowledge for the global academic community.

The 12th ICAANE Scientific Advisory Board (Pascal Butterlin, Peter Fischer, Tim Harrison, Wendy Matthews, Adelheid Otto, Glenn Schwartz, Ingolf Thuesen) proved extremely helpful in steering the Congress out of controversies and helped taking strategic decisions at all steps. The energy and dedication of the 12th ICAANE Unibo Executive Team (Michael Campeggi, Vittoria Cardini, Francesca Cavaliere, Claudia D'Orazio, Valentina Gallerani, Gabriele Giacosa, Elena Maini, Eleonora Mariani, Chiara Mattioli, Jacopo Monastero, Valentina Orrù, Giulia Roberto, Marco Valeri and Federico Zaina) have been admirable before, during and after the Congress. The volunteers Vanessa Ferrando, Noemi La Cara, Ylenia Viggiano and Elena Bandiera generously gave us their time and talents, and G. Roberto designed all the graphics. Outstanding in their roles have been C. D'Orazio as Scientific Secretary of the Congress and F. Cavaliere as Editorial Coordinator: we are all indebted to their rigorous and meticulous organizational skills.

Harrassowitz Verlag with its Director Stephan Specht was as dedicated as it can be to the Congress and accepted to publish our Proceedings in Golden Open Access, while Jens Fektenheuer has been a solid reference for all technical issues. The care and passion with which Federica Proni of Te.M.P.L.A. has typeset these two volumes cannot be praised enough. In releasing these Proceedings to the press, together with the other Editors we hope that they will represent a useful service to an international scientific community which is growing stronger and more closely knit after each ICAANE, hopefully standing up to the grave challenges lying in front of us for the protection, study, conservation and presentation of an ever more endangered cultural heritage.

The Earliest Copper Smelting Activity in South-Eastern Arabia. Some Preliminary Results from Al-Khashbah

Claudio Giardino*, Carlo Bottaini** and Conrad Schmidt***[1]

Abstract

Some very early evidence of copper metallurgy was found at Al-Khashbah, in the Shamal Al-Sharqiya governorate, near Sinaw, Oman. The site lies at the southern foothills of the Al-Hajar Mountains, rich in copper ore deposits. The earliest findings were ^{14}C dated to the end of the 4th millennium BC. Many crucible fragments were recovered in one of the monumental round structures, so-called towers, which characterize the site, Building V. These fragments are currently the oldest evidence of copper smelting activity on the Arabian Peninsula. The paper presents the preliminary results of the archaeometallurgical investigations carried out on these crucibles with Optical Microscopy (OM) and Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDS). The results indicated that at Al-Khashbah metallic copper was produced from ores using rather primitive techniques, such as crucible smelting. Similar techniques are also attested elsewhere in Asian and European prehistoric contexts during the very beginning of metallurgical activities.

Introduction

A significant collection of materials for the production of metals has been found at Al-Khashbah: the site, which covers an area of *c.* 12.5 km^2, is located at the southern foothills of the Al-Hajar mountains (Schmidt and Döpper 2019), tens of kilometers away from the nearest copper ore deposits. The archaeological excavations carried out at Al-Khashbah in the last few years recovered a large collection of materials, i.e., slags and furnace fragments, highlighting that the site worked like a copper workshop from around 3200 BC (Döpper and Schmidt 2019; Döpper 2020).

The rich copper ore deposits determined the social and economic development of the prehistoric communities of Oman. Textual sources testified the large-scale trade of copper between Oman and Mesopotamia in the 3rd millennium BC (Magee 2014: 114-118). Many slag heaps belong to the period of intense exploitation that occurred during the Bronze Age: Batin in the Wadi Nam, Wadi Sahl, Assayab, Bilad Al-Maidin, Mullaq and Tawi Ubaylah (Giardino 2019: 96). Of particular note is al-Mayassar, a mining and smelting site at Wadi Samad, which was excavated by the German Mining Museum of Bochum (Potts 1990: 123-125; Weisgerber 2007).

The presence of such an ancient smelting activity at Al-Khashbah sheds new light on the few 4th millennium BC metal artifacts from Oman. They came from the site of: Ra's al-Hamra RH-10, in the Qurum area near Muscat, from As-Suwayh SWY-2; from Ras Al-Jinz RJ-1 (Period I) in the Ja'alan; and from Wadi Shab GAS-1, a coastal site about 70 km north Ra's

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al Hadd (Giardino 2019: 29-30). The XRF analyses performed on these materials showed that early Omani copper artefacts had a similar composition to the finds of Ra's al-Hamra RH-10 and Wadi Shab GAS-1 (Giardino and Paternoster 2019: tables 12.1-12.2, fig. 12.3). The collections recovered at both these sites consisted in awls and hooks mainly manufactured with almost pure Cu. Arsenic was rarely present, not exceeding 3%, data that led to consider its occurrence as unintentional and related to the mineral composition used in the manufacturing process.

The appearance of metal during this period constitutes one of the changes that led to the transformation of Oman's prehistoric society, such as the beginning of pottery manufacture and fish preservation techniques. Probably, the need for metal procurement by the cities of Mesopotamia had contributed to this development and was the stimulus of new technologies which came from Mesopotamia and southern Iran. However, the local communities of Oman have effectively integrated these technologies into their culture (Cleuziou and Tosi 2007: 80-91).

The site of Al-Khashbah was not located in the immediate vicinity of metal outcrops; therefore, it conformed to the pattern already observed in the Near East, where the first metallurgy was centered in settlements located outside mining areas (Craddock 2000: 153; Hauptmann 2007: 217).

The Site

Between 2015 and 2019 the Institute for Ancient Near Eastern Studies of the University of Tübingen excavated a monumental stone building at Al-Khashbah, which lies in northern Central Oman, about 15 km north of the city of Sinaw (Fig. 1). Building V was one of several early Bronze Age buildings in Al-Khashbah, and definitely the oldest, as proven by many ^{14}C dates (Schmidt and Döpper 2019: 273, fig. 10). Beyond that, its formation at the end of the 4th millennium around 3100 cal BC makes it the oldest known so-called "tower", a monumental structure in Eastern Arabia. The building was characterized by a massive round stone wall measuring 25 m in diameter, the result of a re-building still within the 4th millennium BC (Fig. 2, left). This stone wall with a preserved height of up to 1.50 m replaced a former mud-brick wall on the same spot, of which only small parts had survived. The foundation pit for the stone wall was so broad, that a massive amount of large stones was necessary to fill the gap. Aside from the former outer mud-brick wall, the layout of the original tower was very well preserved in the shape of compartments made of mud-brick walls, and in the east by a combination of mud-brick and stone walls (Fig. 2, right). Only small modifications were observed here. In addition to the interior architecture, the excavations revealed a series of smaller stone and mud-brick walls outside of Building V (Fig. 2, right, A). While the south was dominated by three more or less parallel running stone walls, the structures in the north consisted of mud-brick walls, a heap of reddish, heavily burned material with lots of prills, and unfortunately only a partly preserved stone installation, which looked like a corridor, with an adjacent rectangular mud-brick installation (Fig. 2, right, B).

The finds from Building V indicated it to be a copper workshop, a rather specialized function of the structure. Directly above the bedrock, on which the tower was founded, there was a thick layer of copper-rich slag. Thousands of crucible fragments, with or without slag attached to them, as well as prills, indicated that smelting was conducted in or nearby the building (Figs. 3-4).

The Crucibles

The ceramic fragments with strong traces of heating that were found inside Building V belong to vases of different shapes.

It should be emphasized that these vessels, that the other finds from smelting activities, belong to two different and well-identified moments in the life of the site. Furthermore, the different chronology of these two distinct phases could be precisely identified thanks to a series of radiocarbon dates. They were ascribed to two distinct chronological horizons, an "Older Phase", radiocarbon dated to 3300-3000 BC, and a "Younger Phase", dated to 2900-2700 BC. The archaeometric analysis carried out on the finds did not indicate differences between the oldest and most recent pieces.

A remarkable feature of these ceramic fragments of crucibles was their interior part being black, vitrified and partially sintered by heat. Some copper inclusions were embedded on the slagged surface, converted into green malachite. The vessels were of different shapes, generally open, such as bowls. The bottom appears to usually be flat, with a diameter between 9 and 16 cm, so that it could rest stably on the ground during smelting operations. It was not easy to establish the overall height of the vases, given their fragmented state, but in some very open bowls it must not have exceeded 5 cm by much. In the items in which the rim was preserved, it was possible to approximately reconstruct the diameter at the mouth, between 13 and 20 cm. In the specimens in which the rim was preserved, the interior also appeared slagged, an indication that the vase must have been completely filled by the charge. The walls, in reddish impasto with inclusions, had a variable thickness from 1 to 2.5 cm: the crucibles from Al-Khashbah had relatively thin walls.

Together with the crucible fragments, pieces of copper ore were collected, carefully crushed into pieces measuring 1-3 cm in size. Small copper spheroidal droplets were also found. Their size was below one cm. They were a clear indication that smelting operations took place at the site and they were carried out inside the partially vitrified vessels. Due to the thermal effect, the mineral gangue and the copper ore placed in the vessel reacted with the walls' silicate components of the crucible, producing slag adhering to the inside of the vessel. The chemical-physical reactions that led to the transformation of the mineral into metallic copper took place inside these ceramic containers. We were therefore in the presence of the reduction process known in literature as "crucible smelting" (Craddock 1995: 126-127; Rehren 2003: 208-209).

The smelting crucible technology

The crucibles for smelting differ from ordinary crucibles in size and walls coarseness. The smelting crucibles generally had an open shape, with a diameter between 18 and 40 cm – even if the early crucibles from the Near East seemed to be generally smaller, 10-15 cm diameter (cf. Hauptmann 2007: 217-218) –, with a wall thickness of less than 1 cm. Ordinary crucibles were smaller (diameter 10-15 cm), the walls thickness exceeds the cm.

The reduction vessels' operation was essentially simple: the crushed mineral was added to the burning charcoal and likely more coal and mineral were added until the load was complete.

Temperatures in the order of 1,100 to 1,200 °C were reached inside the vessel using blowpipes. The real problem was not to reach these high temperatures, but to maintain them. Measurements carried out in experiments indicated that, when using blow pipes, the aerated point could easily reach 1,200 °C; however, the temperature dropped to 800 °C when the blowing is stopped (Hauptmann, Bachmann and Maddin 1996: 6). Studies carried out on the crystalline components of the reduction crucibles indicated that the core of the vessel wall did not exceed 1,000 °C (Gómez Ramos 1999: 183). This result confirmed that the main calorific source was inside the vessel and not outside of it (Rovira and Ambert 2002: 97).

The final product of the smelting had to be formed by a heterogeneous mass in which partially reduced minerals and metal droplets were mixed together by the slag. It was necessary to break the pot when this mass stuck to the ceramic: to separate the metal, all material had to be crushed. Therefore, copper recovery had to be done by crushing the smelting product with the help of stone hammers, mortars and pestles. Many of these lithic tools were recovered at Al-Khashbah. Smelting crucible technology allowed the treatment not only of oxide and carbonate, but also of sulfide copper ores.

Crucible smelting technology was reported on many sites with early metallurgy. The earliest evidence of metallurgical reaction vessels was recovered in Iran, from Tepe Ghabristan and Tal-i-Iblis: they can be ascribed to the 5th millennium BC (Majidzadeh 1979; Dougherty and Caldwell 1966). Early smelting crucibles were from Belucistan, at Merhgarh III, dating back to the first half of the 4th millennium BC (Jarrige 1984).

A large quantity of copper ore (malachite and atacamite), copper prills and smelting crucible fragments were also recovered in the Egyptian settlement of Buhen, below the Second Cataract (northern Sudan); this evidence can be ascribed to the Early Dynastic Period, i.e. early 3rd millennium BC (El Gayar and Jones 1989; Craddock 1995: 130-131). In the Levant evidence of crucible smelting came from Israel and Jordan. In the Beersheva valley, copper ore and crucible fragments were recovered in the Chalcolithic village of Shiqmim (Shalev and Northover 1987). The remains of crucible smelting found in the Faynan District, in southern Jordan, particularly in Wadi Fidan 4 – WF4, were extensively studied. Wadi Fidan 4 was a settlement located on the plateau of a small hill in the lower course of the Wadi Fidan, dated to the middle of the 4th millennium BC; there, stone hammers, crucible fragments, prills and lumps were recovered. The ore was transported to be processed into the settlement, located some distance from the outcrops. The smelting activity was organized on a level of "household or workshop metallurgy" (Hauptmann 2007: 136-140, 145-150, 157-228).

In prehistoric Europe, over 30 sites were reported from the Iberian Peninsula, where fragments of smelting crucibles were found, including Zambujal (Torres Vedras, Portugal), Los Millares and Almizaraque (Almeria, Spain). The technique appears in Copper Age settlements (end of 4th – beginning of 3rd millennium BC), but it was also documented in Early and Middle Bronze Age contexts, at sites of the El Argar culture (Rovira and Ambert 2002: 91-93, fig. 1). In southern France, the best known site was that of Al Claus (Tarn-et-Garonne), datable to the Copper Age (Carozza 1998; Rovira and Ambert 2002: 99-101). In Italy, evidence of crucible smelting was in the Chalcolithic settlement of San Carlo – Cava Solvay (San Vincenzo, Livorno), in the Campigliese Mountains; copper prills, fragments of tuyères and crucibles were found. The site was radiocarbon dated to 3400-3100 BC (Artioli *et al.* 2016).

Evidence of crucible smelting was recovered also in South-east Asia: in central Thailand, at Non Pa Wai in the Khao Wong Prachan valley, where thousands of thick-walled crucible fragments dated to the 1st millennium BC. The copper ore available at the site consisted of chrysocolla and weathered copper sulfides (Pigott and Natapintu 1988: 159; Craddock 1995: 135).

Methodology

Analyses on Al-Khashbah materials were carried out by Optical Microscopy (OM) and Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDS). A highly efficient instrument for these archeometallurgical studies was in fact the scanning electron microscope (SEM) equipped with an X-ray fluorescence micro-analyzer. It allowed us to observe the microstructure while providing a virtual image of the chemical composition of the structural phases of the sample being observed. Moreover, with the EDS it was possible to determine the elementary chemical composition of the phases being investigated (Rovira and Ambert 2002: 93). The optical microscope was complementary to the SEM. They allowed us to identify the poor compositional homogeneity that characterized the crucible slags compared to those normally produced in a smelting furnace (Rovira and Gómez Ramos 2003: 37-38). The lack of homogeneity of the slag materials made global analyzes of little use as indicators of slag nature. The identification of the constituent phases were much more useful as they were directly related to the technological problems we were trying to solve.

The optical microscope used in this study was a Leica DM2500P with a digital camera Leica MC170HD, coupled to a PC with the LAS V 4.4.0 software. Observations were carried out under 20x, and 50x magnification, in bright field illumination mode.

SEM-EDS allowed us to obtain elemental analysis of the samples and high resolution images. The analysis was performed with a SEM HITACHI S-3700N interfaced with a QUANTAX EDS microanalysis system equipped with a Bruker AXS Xflash Silicon Drift Detector (129 eV Spectral Resolution at FWHM/Mn Kα). The following conditions of analysis were used: 20kV accelerating voltage, *c.* 10 mm working distance, and 90 µA emission current.

Results

We analysed, in addition to some crucible fragments, copper prills and a small ingot (inventory no. KSB 17H-i0385). The copper ingot was small, highly oxidized, flat ovoid in shape (cm 3 x 2.5 x 1.1) and with only internal remains of a copper core. The metallography of the ingot's interior revealed a strong corrosion which spared only a few residual islands of non-mineralized metal (Fig. 5). The ingot, observed in the SEM, revealed that the metal was almost pure copper, with only slight traces of As. The structure was heavily attacked by corrosion, with gas vacuoles, perhaps due to excessive aeration. The dominant element was cuprite (Cu_2O) (Fig. 6). This was probably the result of the melting of the tiny prills obtained during the smelting process into a small "ingot". The process, divided into two steps, also allowed considerable savings in energy - and therefore fuel - since melting metal requires less energy than smelting (Tylecote 1976: 16; Hauptmann 2007: 228).

The analysis with EDS of a small spherical prill (diameter cm 0.5: inventory no. KSB 17H-i0262) revealed that it also consisted of almost pure Cu. Large rounded Cu grains were observed with SEM; the metal part was partially mineralized in chlorides (Fig. 7).

The examination of a crucible fragment belonging to the earliest phase (3300-3000 BC) showed that the slagged outer part had penetrated deeply into the pottery wall, sintering it (inventory n. KSB 17H-i2355). Its internal surface was completely slagged, with outcrops of green oxidized copper patinas; the external side was only slightly touched by the heat. SEM micro-mapping of the slag showed the presence of metallic copper nodules and iron crystals in a silica and calcium matrix (Fig. 8), highlighting a silicate fibrous structure. Within the silicate structure, crystals of delafossite ($CuFeO_2$) were observed (Fig. 9). This compound, with a temperature formation around 1,150 °C, was an excellent indicator of the reduction vessel working temperature (Rovira and Ambert 2002: 96). It was also a stable compound in an oxidizing environment, so its presence was further evidence that the process occurred with periods of an oxygen-rich atmosphere.

Metallographic analysis carried out on a crucible fragment (inventory no. KSB 17H-i0031) belonging to the more recent phase (2900-2700 BC) showed very similar structures. In the SEM image the presence of delafossite crystals was located together with Cu droplets (Fig. 10). This was a clear indication that even in the most recent phase, the smelting technology was similar to the old one.

Conclusions

According to the data presented in this study, the following preliminary conclusions can be evidenced:

1. The quantity of crucible fragments found during the excavation revealed that Al-Khashbah was an important production center. It is likely that an intense activity, possibly of autonomous experimentation, took place since the end of the 4th millennium BC, aimed at satisfying the new, arising needs of the society.
2. Copper-based metals production was mainly intended to manufacture objects made of pure copper.
3. The opportunity to analyze smelting crucibles from two different chronological phases made clear that no relevant differences, in terms of technology, could be found among the fragments from the end of the 4th and those from the beginning of the 3rd millennium BC. In fact, data revealed that this primitive smelting technique must have remained in use, without significant modifications, for over half a millennium.

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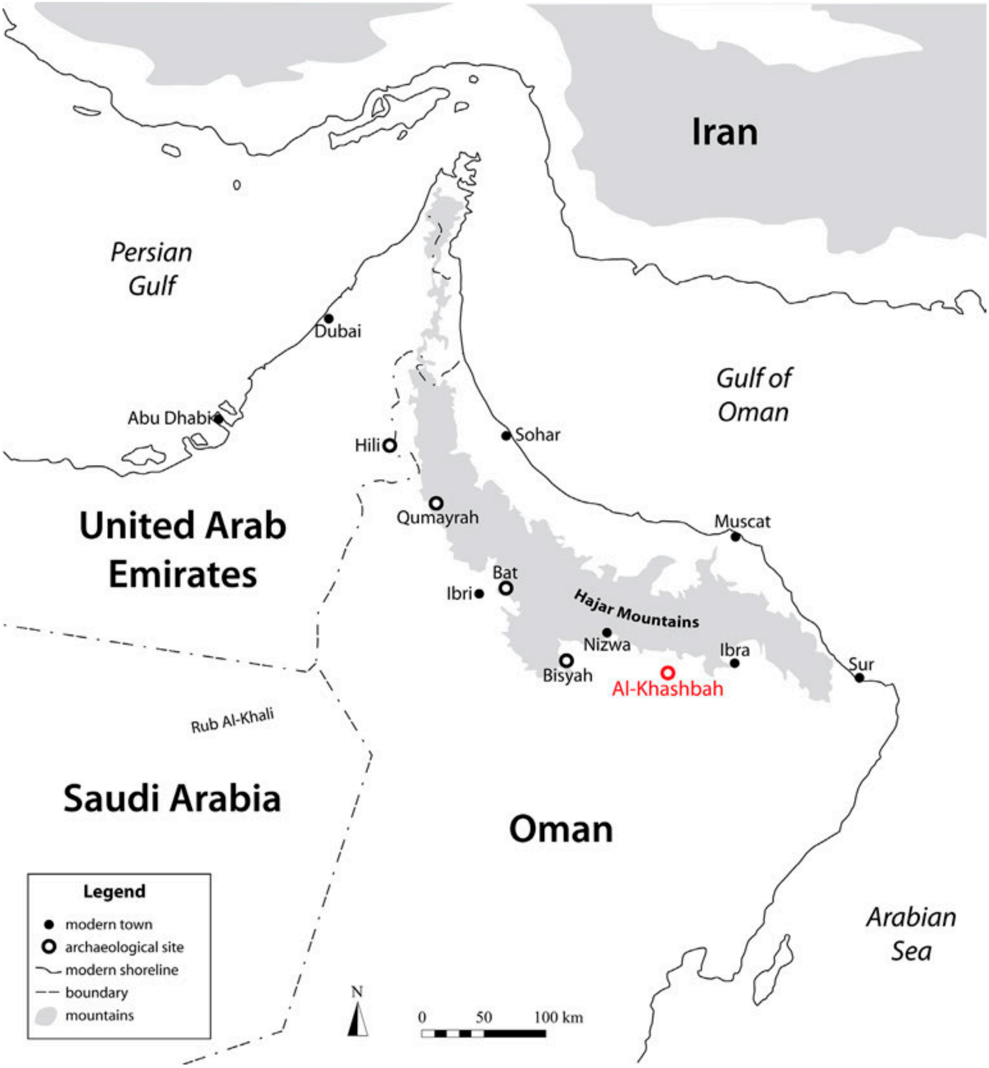


Fig. 1: The site of Al-Khashbah in the Sultanate of Oman

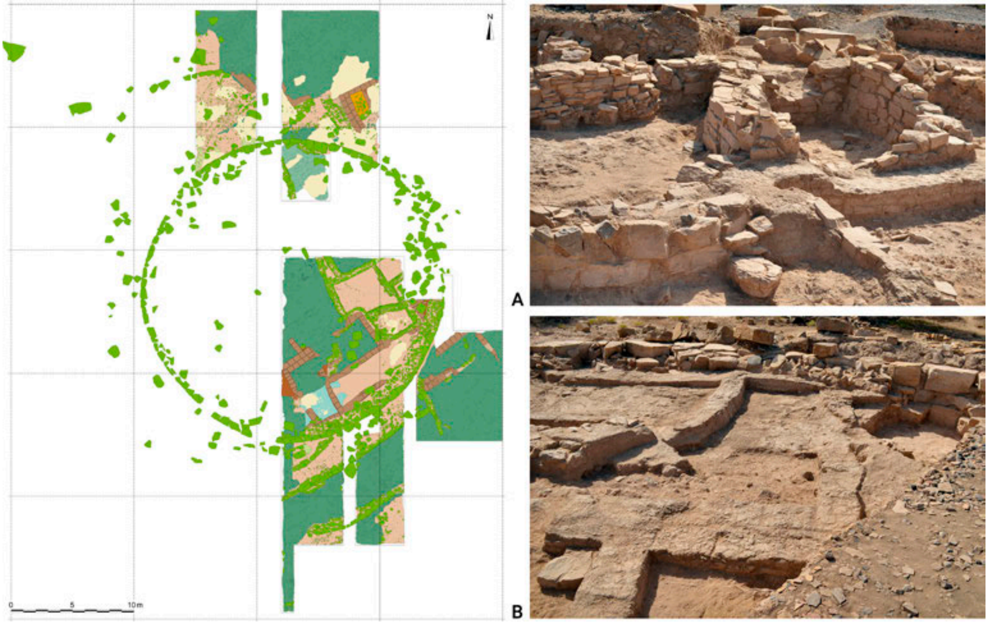


Fig. 2: Plan and interior of Building V

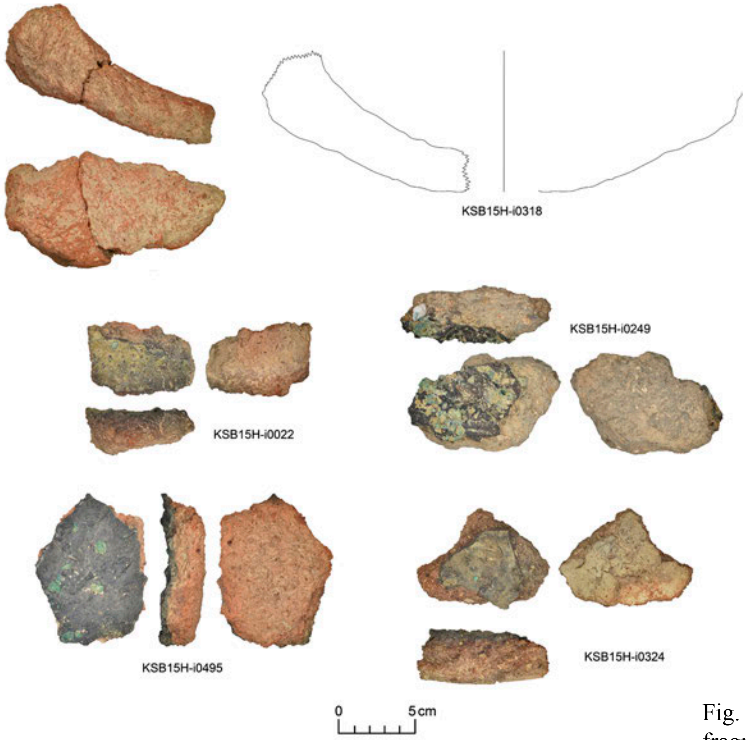
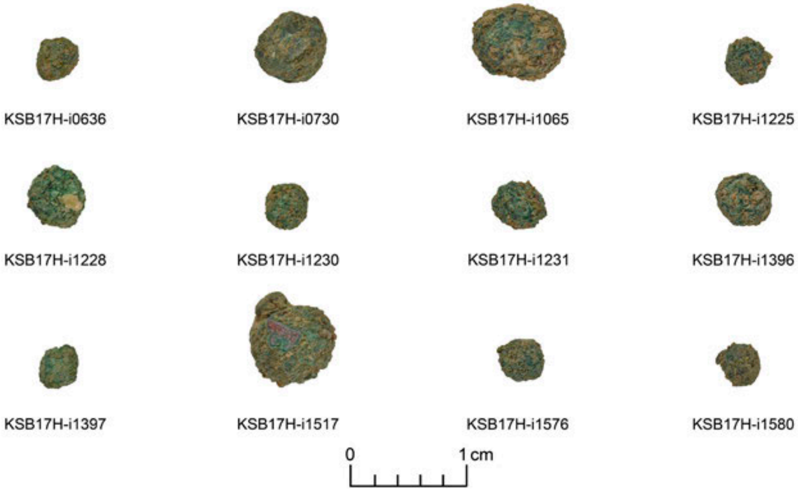


Fig. 3: Smelting crucible fragments from Building V



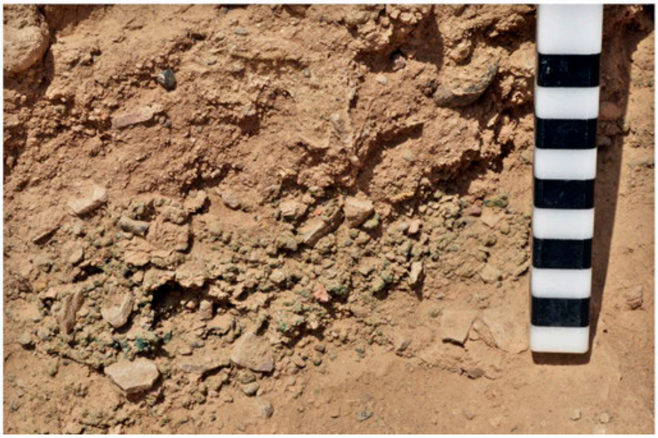


Fig. 4: Copper prills and layer of copper-rich slag from Building V

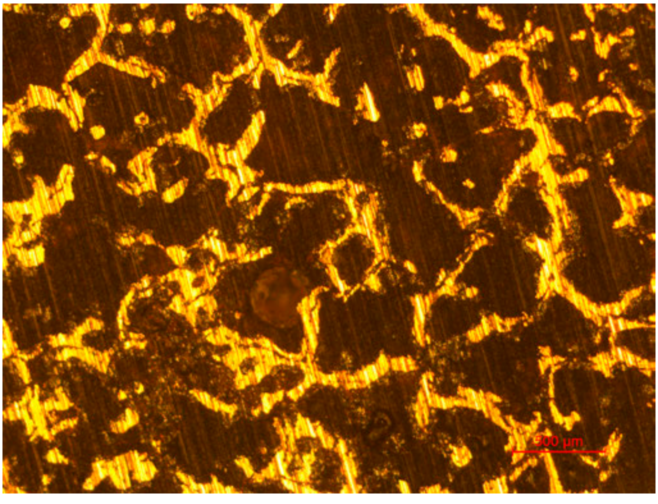


Fig. 5: Ingot KSB 17H-i0385: optical metallography after etching, 10x

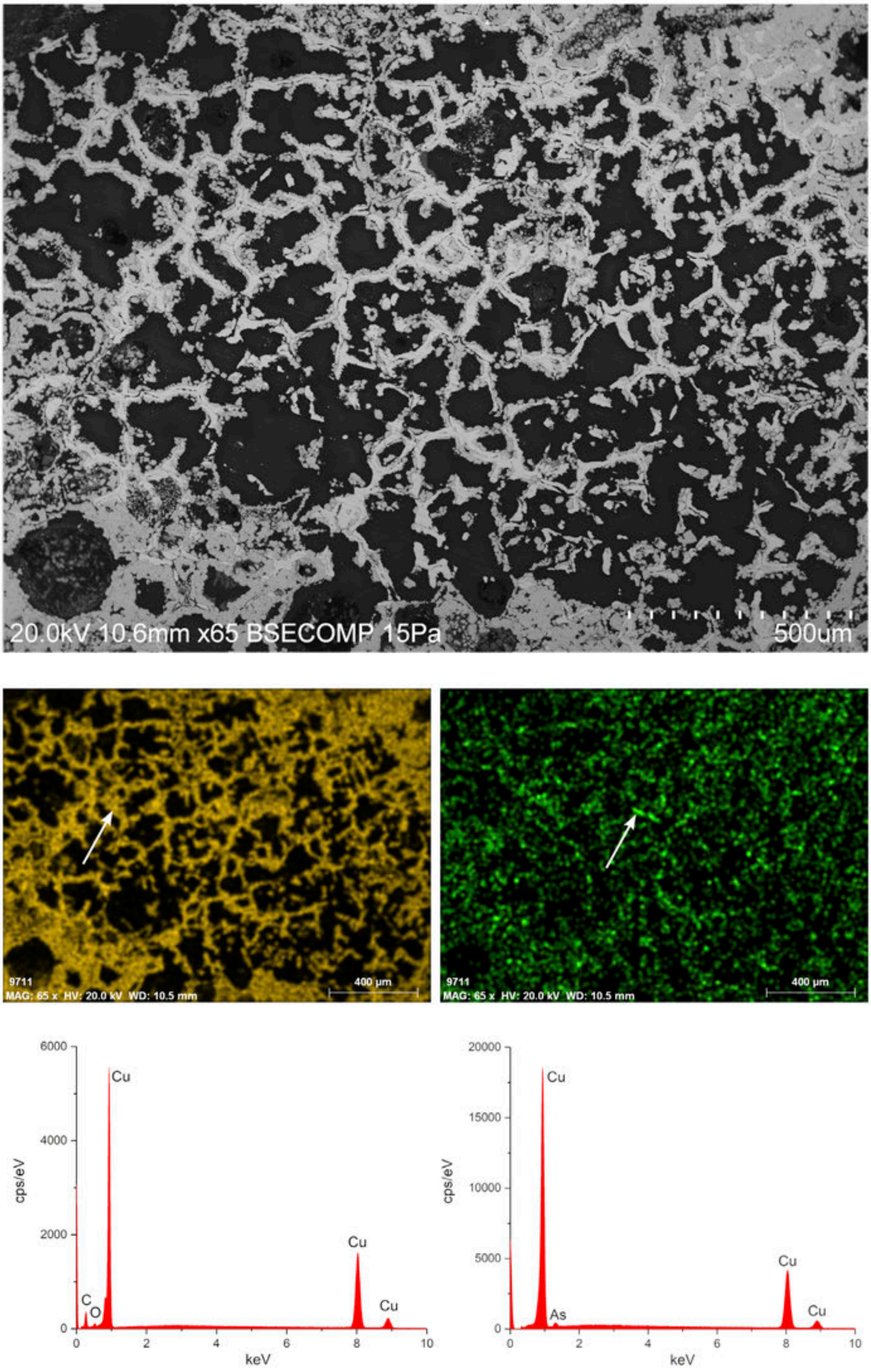


Fig. 6: The ingot KSB 17H-i0385: SEM micro-mapping image and microanalysis. The arrowheads in the mapping imaging refer to the points analyzed by EDS

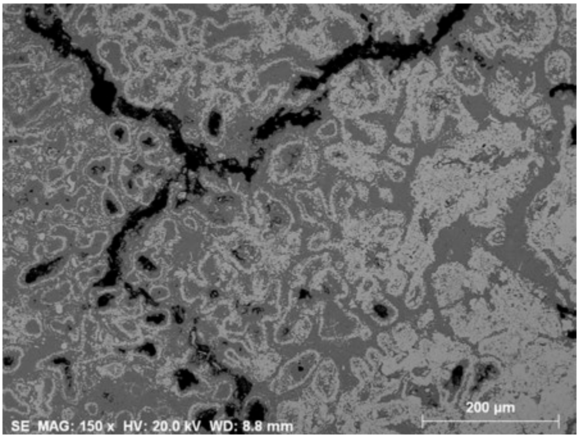


Fig. 7: Copper prill KSB 17H-i0262: SEM image. Pure copper is in brighter gray (point 1); chlorides are in darker gray (point 2)

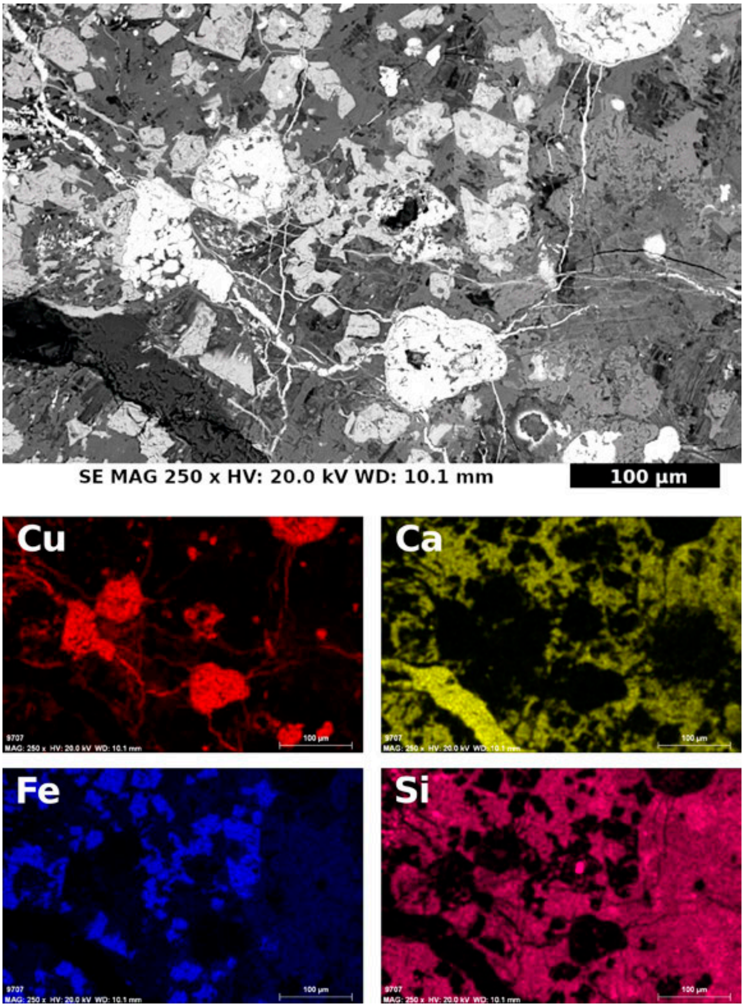


Fig. 8: Crucible KSB 17H-i2355; SEM micro-mapping

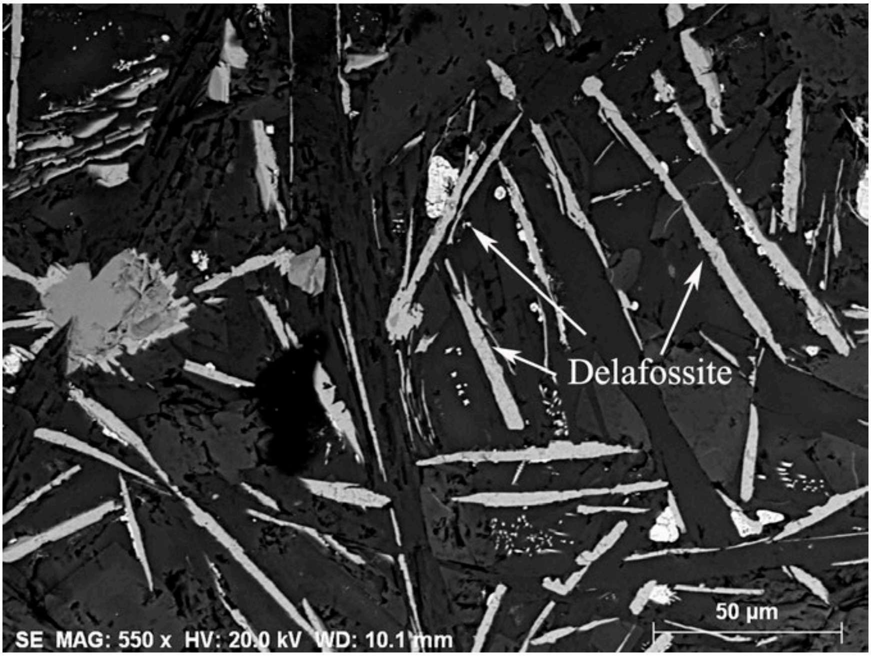


Fig. 9: Crucible KSB 17H-i2355; SEM image with delafossite acicular crystals within the silicate structure

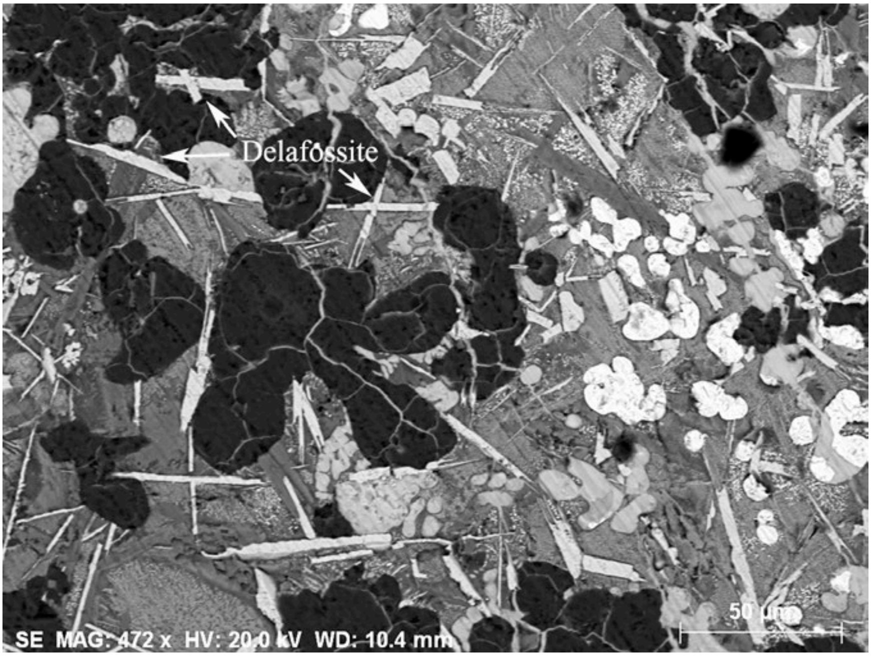


Fig. 10: Crucible KSB 17H-i0031; SEM image with delafossite crystals and copper microprills