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Inherited Practices: The Heritage of Metalworking in Ancient Egypt between Techniques and Iconography: Wadi Nasab (Sinai) as a Case Study

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Abstract

The metallurgical activities in ancient Egypt began during the late Predynastic era, with Wadi Dara in the Eastern Desert providing early evidence of systematic metalworking. Copper was the first metal to be smelted and melted, marking the first steps of ancient Egyptian metallurgy, and the later adoption of bronze represented a significant technological leap. Yet, key metallurgical operations, including smelting, melting, casting, hammering, and annealing, remained largely unchanged from techniques used during the Copper Age.

This paper will integrate the recent archaeological discoveries at Wadi Nasab in South Sinai, including evidence of large-scale copper smelting workshops, administrative buildings, and advanced metallurgical facilities, with the rich heritage of metalworking scenes depicted in ancient Egyptian tombs, primarily from the Old Kingdom. By correlating the material remains from Wadi Nasab, which show continuous metallurgical heritage from the Old Kingdom through the New Kingdom and illustrate state-level organization and industrial scale production, with the visual and textual evidences from tombs, this study aims to deepen the understanding of ancient Egypt's metalworking traditions and their socio-economic contexts.

Keywords

Wadi Nasab;
Metallurgy workshop;
Sinai;
Copper;
chaîne opératoire;
Metalworking Scenes;
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1. Introduction

The study of ancient Egyptian metallurgy is an emerging and interesting field that connects modern heritage to ancient science and vice-versa. While extensive analyses of the chemical composition and technology science of ancient Egyptian metal objects have been conducted, there are still new data, techniques, manufacturing processes, and working conditions of metalworking in ancient Egypt, that can be understood from new discoveries.

The ancient Egyptians established numerous sites, all over Egypt, for conducting metallurgical activities,[1] among which the site of Ayn el-Sukhna[2] offers a good model of a copper *chaîne opératoire*, where metallurgical furnaces from the Middle Kingdom were found (Abd el-Raziq Castel, Tallet & Fluzin 2011, p. 147). The large number of furnaces, approximately a hundred melting furnaces and ten melting batteries found by the French Mission,[3] presented an exceptional opportunity to study metallurgy in ancient Egypt. The furnaces were used to smelt malachite (Fig. 1)[4] which was mined on the Eastern side of the Red Sea, i.e. in Sinai, in order to obtain liquid copper that was formed in ox-shaped ingots (Mansour 2024, p. 89–103), and finally transported to the Nile Valley (Abdel-Raziq, Tallet, Castel & Marouard 2012, p. 7).

The second major site is Wadi Nasab, a key center of copper production in the New Kingdom. Located in South Sinai, it was part of a broader mining district that included Serabit el-Khadim (Mansour 2014, p. 13), Wadi Maghara, Wadi Kharig (Mansour, 2014, p. 21), and Wadi Sur (southwest of Wadi Nasab). This industrial zone supplied Egypt with vital resources of copper and turquoise.[5] Owing to its strategic position near the turquoise mines of Serabit el-Khadim and its access to transport routes leading to the Gulf of Suez, Wadi Nasab maintained connections with coastal sites such as Tell Ras Budran[6] (Mansour 2014, p. 29) which functioned as important departure points for Egyptian metallurgical expeditions.

Together, these sites demonstrate how mining and metallurgical operations were incorporated

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[1] For a complete and detailed list of these sites, see: (Pfeiffer, 2013, 70).

[2] The site dates to the Old Kingdom, and is located 120 km east of Cairo on the western shore of the Red Sea. I have met Georges Verly, and we had a mutual discussion and compared iconography with the archaeological find at Ayn el-Sukhna.

[3] This mission included four parties: Institut français d'archéologie orientale (IFAO), Orient et Méditerranée (Ivry-sur-Seine), Equipe Mondes pharaoniques (CNRS, UMR 8167), Association mer Rouge-Sinaï (AMeRS), and Honor Frost Foundation, Sorbonne Université.

[4] A green semi-precious stone that comes from Sinai. The mining expeditions that were dispatched from the Nile valley upon the request of the king, refer to the mining of malachite. It is known in AE as *sšmt*: (Harris, 1961, 132–134).

[5] To read more on turquoise and its roles in ancient Egypt, cf. (Mansour, 2014).

[6] Tell Ras Budran is an ancient Egyptian fort site on the Sinai Peninsula, located about 150 meters from the Gulf of Suez. It lies near key ancient mining regions for copper and turquoise, including Wadi Maghara to the southeast and the temple complex of Serabit el-Khadim to the east.

into state-organized expeditions sustained by structured labor, resource administration, and transportation networks extending from the Nile Valley. Because it was situated at the intersection of resource-rich zones and desert trade routes in Sinai, Wadi Nasab served not only as a source of raw materials but also as an important center of technological and industrial innovation in ancient Egypt (for state-organized expeditions see: Mansour 2014, p.31-44; Seyfried 1981, p. 204).

In the meantime, with the recent publications of Martin Odler's *Copper*[7] *in Ancient Egypt: Before, During and After the Pyramid Age (c. 4000–1600 BC)* (Brill, 2023) (Odler, 2023, vol. 132) provides the first comprehensive overview of copper use from the Predynastic to the Second Intermediate Period, reconstructing *chaîne opératoire* sequences and emphasizing Egypt's technical sophistication and interaction with broader Mediterranean networks.

This work complements experimental studies such as Rademakers et al. (2020-2021) and G. Verly, et al. "Minerais arséniés et production d'alliages de cuivre" (Verly et al. 2022, 19–40) on reconstructing ancient metallurgical processes in ancient Egypt, as well as Davey's "Out of the Fiery Crucible" (2023) (Davey & Hayes 2023, 11–28) and Hampson's *Make It According to Plan* (2022), (Hamspon 2022) which explores production systems, resource logistics, and craft organization within ancient metallurgical industries.

These publications conform with field data from ongoing excavations: the French mission at Ayn el-Sukhna on the Red Sea—120 km southeast of Cairo, and a major site for Middle Kingdom copper ingots productions, the Belgian mission at el-Kab—80 km south of Luxor—and the Egyptian mission at Wadi Nasab in southern Sinai (a key mining zone of the New Kingdom). Together, they produce a uniquely comprehensive foundation for an integrated narrative of early Egyptian metallurgy—connecting laboratory science, excavation evidence, and theoretical modeling into a coherent understanding of technological and social complexity in pharaonic metalworking.

In the past, the investigation into ancient Egyptian metallurgy had the following gaps in its historiography:

- The gap between science and heritage: Former investigations carried out thorough chemical/archaeometrical studies of the metals found but failed to relate the scientific results to the manufacturing process as well as the working environment of the metal workers.
- The gap between iconography and materiality: While tombs contained imagery concerning the metal work, it was viewed more as artistic expression or burial ritual instead of correlating it with material reality found at excavation sites.
- The focus on final products: Formerly, the studies concentrated more on the chemical analysis of the final luxury products and not the chain of operation discovered at industrial smelting sites.

Therefore, this paper intends to answer two questions:

- To what extent do the archaeological remains at Wadi Nasab—such as furnace batteries and metallurgical tools—materially validate the technical "chaîne opératoire" depicted in Old Kingdom tomb iconography?

[7] Wadi Dara is located at the north of the Eastern Desert. It extends into the Gulf of Suez, north of Gebel el-Zeit. The copper mines are located at approximately 50 km from the coast. See: (Castel, Mathieu, Pouit, El-Hawari, Shaaban, Hellal, Abdallah & Ossama, 1996, 15).

- How does the evidence of large-scale, state-organized production at Wadi Nasab illustrate the continuity and evolution of Egyptian metallurgical knowledge from a specialized craft into a centrally managed industrial enterprise?

2. Methods

The proposed research will take a holistic approach by integrating knowledge on heritage and science through combining archaeological finds with the iconography of ancient Egyptian tombs. The study will combine the latest discoveries made during the 2021-2025 Egyptian mission in Wadi Nasab, which uncovered large-scale copper smelting facilities, administrative structures, and highly evolved metallurgical centers, with the heritage preserved in metalworking scenes in tombs dating back to the Old and New Kingdoms. Through combining physical archaeological finds with the imagery and textual heritage in the tombs, the study hopes to further understand the history and socio-economic background of ancient Egypt's metalworking tradition.

For the purposes of the archaeological stratigraphic analysis, the team will use data obtained from the excavation conducted in 2021-2025 of the Egyptian mission at the Wadi Nasab archaeological site to analyze the metallurgical installations, the slag waste material, and other toolkits used. Although the industrial nature and completeness of the metallurgical process are proven by large quantities of slag materials, the transition periods between furnace shapes such as U-shaped, shaft, and pear-shaped are still hypothetical.

Iconographic correlation is through examining scenes of metalworking and the texts that accompany them in the tombs of Old Kingdom figures like Mereruka, Ty, and Ankhmahor, to trace continuity in technology and ensure that the use of tools in the pictures was practical. Technology reconstruction makes use of discoveries of furnace batteries and special tools such as the tuyère and crushing equipment in order to chart the whole process of making copper starting from breaking up the rock until purification of the metal.

3. History of the Excavations of Wadi Nasab

Several travelers have described the extensive slag heaps produced by copper smelting in the area, rising 6 to 8 feet (about 1.8 to 2.4 meters) high and covering an estimated area of either 500 by 300 feet (approximately 150 by 90 meters) or 250 by 200 yards (about 230 by 180 meters). According to Weill (Weill 1908, p. 126), the presence of water in the Wadi Nasab valley and the ample fuel supply provided by acacia trees likely explain why copper ore, brought from elsewhere, was smelted at this site. Indeed, the abundant spring in Wadi Nasab accounts for the palm garden photographed by Petrie (Petrie 1906, p. 27).

Bauerman (Bauerman 1868, p. 29–30) offers a particularly detailed account of these slag heaps, noting that "numerous clay tuyère-nozzles, with an air passage of about three-quarters of an inch in diameter, were found" among them. The only structures that might have served as furnaces were two small enclosures of unequal size, the larger measuring approximately six feet (about 1.8 meters) square.

In addition, Flinders Petrie (Petrie 1906, p. 51–53) identified slag heaps and surface evidence of copper mining. Subsequent investigations by Egyptian archaeologists in the mid-20th century documented furnaces and mining remains, yet systematic stratigraphic excavations did not begin until the new mission started its work in 2021.

In 2021, the first dedicated Egyptian archaeological mission of the Supreme Council of Antiquities (SCA), led by Dr. Hesham Hussein, set out to examine the extent and organization of copper production at Wadi Nasab. Excavations uncovered extensive slag deposits, smelting workshops, and remarkably well-preserved metallurgical installations. Continued fieldwork in

2025 revealed a large metallurgical complex in the southern sector of the site, comprising multiple layers of furnaces that represent successive phases of copper production. These stratified remains attest to the site's continuous occupation and industrial use from the Old Kingdom through the New Kingdom and into the Nabataean Period (between the 4th and 2nd centuries BCE), highlighting Wadi Nasab's enduring significance as one of ancient Egypt's principal centers for copper production.

In addition, metallurgical tools such as *tuyères* (clay pipes used to direct air into furnaces; see below), grinding stones, and ore-crushing tools (Fig. 2) were discovered. These artifacts provide direct evidence of ore production methods, fuel management, and the precise control of airflow essential for reaching the high temperatures (see below) required in copper smelting. The standardized design of these tools indicates an organized production system operated by skilled craftsmen familiar with metallurgical techniques.

The excavations also revealed production remains such as crucibles, slag heaps, and semi-finished products, including copper cakes, prills, blister copper, and matte. The coexistence of waste materials and refined outputs demonstrates that the *chaîne opératoire*, the complete copper production sequence from ore processing and smelting to refining, was conducted entirely on site.

4. Interpretation and Significance of Metallurgical Technology: Between Iconography and Technical Practice, Connecting Heritage to Science and Science to Heritage

There is a development of metallurgical practices in the images of the Egyptian metalworking process, especially those involving the construction and use of furnaces, crucibles, and other related heating devices. There is a process of continual development and improvement in terms of pyrotechnic knowledge and its application. This paper aims to analyze three key tools that were used in the production of metals through metallurgical techniques; these are the crucible, furnace, and bellow pipes.[8]

4.1 Crucible and Furnace (Fig. 3)

During the Old Kingdom, furnaces typically assumed a funnel-shaped formation, activated through the use of heating tubes to generate airflow. The most detailed depiction of this type occurs in the tomb of Mereruka (LS10, Teti Cemetery, PM III. 525-534) (Fig. 4), where two smelting pots are shown placed back-to-back within a funnel-shaped structure. A comparable furnace appears in the tomb of Ty (D22, PM III, 468-478), although only its exterior is represented. Overall, Old Kingdom furnaces consistently conform to this characteristic shape, which reflects an early, yet standardized, approach to metallurgical practice (Garènne-Marot 1985, p. 85–100).

The use of crucibles in the Egyptian metallurgy industry could have been inspired by the Mesopotamians, who developed these objects much earlier. The technology behind their design can be considered in the context of general developments in metallurgy in the ancient Near East. Tylecote asserts that the earliest furnaces were based on either natural or forced draft technology.[9] He observed that by the fourth millennium BCE, potters had mastered the

[8] To read more on the role of tomb scenes in reconstructing our knowledge of ancient Egyptian metallurgy, cf. (Mansour, 2016).

[9] Forced draught: a draught mechanically brought (e.g. by fan or blower). Cf. *Indexed Foundry Dictionary* (1979), 527, no. 6128 (1). The induced or natural draught is a draught brought by the difference in temperature, hence, the density and the pressure of the inner and outer atmospheres. Cf. *Indexed Foundry Dictionary* (1979), 527, no. 6127 (1).

technique of creating induced draft furnaces with high enough temperatures to extract copper (Tylecote & Boydell, 1978, p. 28). On the other hand, the earliest forced draft furnaces were probably very basic stone bowl furnaces blown via one or several tuyères, as seen at Timna,[10] where furnaces of this sort were being utilized even during the Chalcolithic Age (around 4500 to 2500 BCE) (Tylecote & Boydell, 1978, p. 28). Such facts can help establish a comparative perspective on the development of furnace technology in Egypt and the possible spread of pyrotechnological ideas in the eastern Mediterranean and the Near East regions.

By the Middle and New Kingdoms, Egyptian furnaces exhibit clear signs of technical advancement and improved thermal control. In this context, the new excavations at Wadi Nasab provide particularly compelling evidences of such innovation. Several types of furnaces including U-shaped furnaces, shaft furnaces, and pear-shaped pit furnaces, all constructed from mudbrick, stone linings, and clay components, were revealed. These furnaces demonstrate careful adaptation to ore quality and available fuel sources, while evidence of *in situ* burning confirms their active use for copper smelting. The coexistence of multiple furnace types at the site suggests an ongoing process of experimentation and technical optimization, emblematic of a dynamic metallurgical tradition.

A review of Old Kingdom metalworking scenes reveals that crucible handling methods remained quite simple during this period (Garènne-Marot, 1985, p. 92). Petrie noted that Egyptians employed a fragile paste to form crucibles, resulting in vessels that would readily dissolve, making it impractical to lift them when filled with molten metal. Consequently, the crucible had to be emptied by rolling it forward on its rounded base. For this reason, the crucible was designed as a hemisphere extended upward, which facilitated tilting in the fire, provided a secure grip for manipulation, and included a spout to allow metal to be poured efficiently (Petrie, 1906, 51, p. 162, fig. 161).

Deep crucibles with spouts thus characterize Middle Kingdom metalworking, whereas shallower and broader vessels became more common in the New Kingdom. In functional terms, crucibles generally featured a rounded base to facilitate handling, a spout for controlled pouring of molten metal, and a narrow neck designed to retain heat and limit oxygen absorption—preventing porosity in the final product.

4.2 Blowing-Pipes

By the end of EBA II–III (ca. 2800–2700 BCE), notable technological progress occurred in Sinai. Surveys by Pfeiffer revealed clay nozzles (*tuyères*) at several sites, (Fig. 5) indicating the use of artificially supplied air in smelting. This innovation, scarcely visible in the Early Bronze Age, became pronounced in the Late Bronze Age. The sites of Wadi Ahmar 1039 and Wadi Zaghra 1041 represent the earliest known examples of such metallurgical activity in Sinai.[11]

[10] The Timna Valley, north of the Gulf of Aqaba, was a major center of ancient copper mining and smelting, active from the fourth millennium BCE to Roman times. Rich in copper ores, it preserves extensive archaeological remains from Egyptian New Kingdom to Iron Age and later industrial activities.

[11] It lies at the eastern feet of the Hus e-Deba massif, to the south of Wadi Riqeita and it dates back to the end of EBA II or III (ca 2700-2300 BC). It consists of a settlement with annexed melting place. The size of the site is about 100 x 60. Cf. (Pfeiffer, 2013, 77).

Blowpipes often had clay tips to concentrate airflow, helping achieve melting temperatures. The charcoal was kept compact with a wooden stick to maintain furnace intensity, as seen in the scenes from the tomb of Ankhmahor (PM III. 512- 515).[12] However, Tylecote noted that blowing tubes were unsuitable for the high temperatures required in metal reduction and melting, as they could fuse with the molten metal. He also argued that the ancient Egyptians had to employ bellows as early as the Old Kingdom to melt metals effectively (Tylecote, 1981, p. 111). Moreover, the hearths employed for smelting in ancient Egypt were constructed using charcoal, a fuel readily available in the eastern desert and Sinai (Fig. 6) (Scheel, 1989, p. 22). The charcoal was especially prized for its ability to attain the high temperatures necessary for metallurgical work, making it the fuel of choice for ancient metalworkers. Experimental research has demonstrated that, with the use of a blowpipe, a single person can elevate the temperature of a charcoal hearth to above 1100°C (Rehder, 2000, p. 76), underscoring the effectiveness of this technique in achieving the intense heat required for smelting (Rehder, 2000, p. 76).

Indeed, the architectural finds in Wadi Nasab, particularly the stone building reused as a workshop, reflect high state involvement. The scale of slag deposits and furnaces suggests mobilization of large, specialized labor forces organized for ore extraction, smelting, fuel production, and transport. This underscores copper's strategic importance for Egypt's economy, military, and symbolic use.

The documentation of the various stages of metal production at the site, along with evidence of administrative oversight and labor organization, indicates a well-structured and centrally managed industrial operation, designed to optimize resource extraction and processing efficiency. Strategically located near other mining areas such as Serabit el-Khadim and well-connected to coastal embarkation points like Tell Ras Budran, Wadi Nasab played a crucial role in transporting raw and processed materials to the Nile Valley, embedding it within Egypt's broader economic and administrative networks.

5. Discussion: Linking Practice and Theory at Wadi Nasab

The long-term occupation at Wadi Nasab, which ranges from the Old Kingdom (circa 2686 to 2181 BCE) to the New Kingdom (circa 1550 to 1070 BCE), illustrates an interaction between technological stability and industrial development. In archaeological layers at the site, there is evidence of recurring construction of furnaces through alternating layers of ash and refractory bricks, as well as changing arrangements of workshops; however, the basic technology for copper processing, such as the bowl furnace process and natural air flow, was consistently preserved. Not only did Wadi Nasab serve as a hub for industrial activities, but it also maintained a continuous technological culture, in which gradual adjustments were made based on accumulated knowledge.

The archaeological materials from Wadi Nasab are another testimony to these developments, which make it possible to recreate chaîne opératoire in great detail. Tuyères of ceramic material, preserved intact and having identical sizes (bore diameters are about 2–3 cm) suggest effective use of air flow for slag separation, while tool kits used for ore crushing (stone mortar) and ingot production (bone-handled chisels) speak for a refined process chain. The change in the scale of metallurgy practiced in Wadi Nasab is also connected with the development of more complex technologies and, probably, division of labor, shifting from an artisanal level, characteristic of

[12] See on this the representation in the tomb of Ankhmhor: a simple wooden stick of medium length could have served the purpose to act as the utensil to keep the fire together.

similar sites during the Old Kingdom period (Timna), to the state-run industrial enterprises of the Middle Kingdom.

Combining the data from the study of physical traces with iconography and ancient texts provides more insight into the industrial nature of the ancient Egypt state, in particular, its economy based on resource extraction. Location of Wadi Nasab in the south of Sinai (supported by administrative buildings of local importance with the seal imprints of royal overseers), combined with the presence of logistics connections with the coast (routes leading through the area with manure indicating the donkey trails and thus confirming connections with such centers as Tell Ras Budran), made Wadi Nasab the core of raw material extraction, state domination, and technological excellence. This is where theory is brought to practice and industrial activity was crucial for pyramid construction and military conquests, which could be made with metal weapons.

Based on the data obtained during excavations in 2021-2025 (the discovery of several smelting workshops with several furnaces, various-sized copper ingots, tuyères for regulating air flow, significant slag heaps as evidence of large-scale activity), it becomes clear that the techniques of metallurgy found at this site closely correspond to the description of ancient Egyptian iconography and texts, particularly Old Kingdom tomb paintings. In conclusion, this makes it possible to say that Wadi Nasab was one of the key metallurgy centers of Egypt, and ancient kings directly supervised it and resource management there.

6. Conclusion: Wadi Nasab as a Keystone of Egyptian Metallurgy

The interdisciplinarity of the studies undertaken at the Wadi Nasab site through archaeometallurgy, stratigraphy, and iconographic synthesis provides a revolutionary understanding of the process of ancient Egyptian metallurgy, providing a bridge between scientific historiography and heritage. The correlation of the evidence obtained from the excavations conducted between 2021-2025 and the iconography in tombs (e.g., similarity of the tuyère structures to those illustrated in the reliefs in the tomb of Ty) proves that the images in the tombs were, in fact, accurate visual depictions of the standardized production processes.

Stratigraphic analysis at Wadi Nasab highlights that the knowledge of metallurgy was a living tradition that scaled with the demands of the state, evolving from Old Kingdom proto-industrial periods to furnace batteries during the Middle Kingdom. Metallurgy started as an expertized specialization, as proved by the findings of slag in early layers, and then transformed into a centralized industry managed by the royal bureaucracy (administration seals), connected through trade logistics with places like Tell Ras Budran. It was crucial for Egypt's economic prosperity and military strength, which provided copper for tools and weapons needed for military campaigns towards Nubia and the Levant. Field archaeology, smelting experiments, and socio-economic modeling prove the extraction and use of mineral resources in Sinai.

Wadi Nasab is, therefore, an exemplar example of how ancient Egypt was a melting pot of social complexity and technological advancement. Through its preserved furnaces, abundance of slag deposits, and artisan precision, Wadi Nasab demonstrates the timeless technical genius of the pharaohs, surviving through all subsequent dynasties. This makes Wadi Nasab one of the key examples of metal production in the ancient Near East, thus making it subject to future research (isotopic analysis of the ore origins).

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8. REFERENCES

1. Abd el-Raziq, M., Castel, G., Tallet, P. & Fluzin, Ph. (2011). Ayn Soukhna II, Les ateliers métallurgiques du Moyen Empire. *FIFAO* 66, Cairo, 147.
2. Abdel-Raziq, M., Tallet, P., Castel, G. & Marouard, G. (2012). The Pharaonic Site of Ayn Sukhna in the Gulf of Suez 2001-2009 Progress Report. In P. Tallet, E. Mahfouz (eds.), *The Red Sea in the Pharaonic Times, Recent Discoveries along the Red Sea Coast, Proceeding of the Conference held in Cairo/Ayn Sukhna 11th-12th January 2009, BdE* 155, Cairo.
3. Bauerman, H. Esq. (1868), Note on a Geological Reconnaissance made in Arabie Petraea in the Spring of 1868. 17-39 *The Quarterly journal of the Geological Society of London* 25.
4. Castel, G., Mathieu, B., Pouit, G., El-Hawari, M., Shaaban, G., Hellal, H., Abdallah, T. & Ossama. A. (1996). Wadi Dara Copper Mines. In F. A. Esmael (ed.), *Proceeding of the First International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artifacts*. Cairo: Ministry of Culture. 15–31.
5. Davey, Ch. J. & Hayes, P. (2023). Out of the Fiery Crucible: Egyptian Old Kingdom metallurgy. *Buried History* 59, 11-28.
6. Garènne-Marot, L. (1985). Le travail du cuivre dans l'Égypte pharaonique : d'après les peintures et les bas-reliefs. *Paléorient* 11/1, 85–100.
7. Hamspon, M. (2022). *Make it According to Plan*: *Workshop Scenes in Egyptian tombs of the Old Kingdom*. Oxford.
8. Mansour, A. (2014). Turquoise in Ancient Egypt: Concept and Role. *BAR* 2602, 13.
9. Mansour, A. (2016). *Metalworking Scenes in the Old and Middle Kingdoms*. Unpublished PhD Dissertation, Alexandria University.
10. Mansour, A. (2024). A Probable Production of Ox-hide Ingots during the Middle Kingdom in Ancient Egypt: Iconographical Perspective. In Th. dePutter & Ch. Karlshausen (eds.), *Proceeding of the International Conference Minerals in Egypt, from Naqada to Alexandria,* Royal Academy for Overseas Sciences Brussels, 3-4 October 2022, Brussels, 89–103.
11. Odler, M. (2023). *Copper in Ancient Egypt, before, during and After the Pyramid Age (c. 4000–1600 BC)* (Culture and History of the Ancient near East vol. 132). Leiden.
12. Petrie, W. M. F. (1906). *Researches in Sinai*. New York: Dutton.
13. Pfeiffer, K. (2013). Neue Untersuchungen zur Archäometallurgie des Sinai. Die Entwicklungsgeschichte der Innovation "Kupfermetallurgie", Studien aus den Forschungsclustern des Deutschen Archaologischen Instituts. *Band* 11, Forschungscluster 2. Innovationen: technisch, sozial, Berlin.
14. Raymond, W., (1908), *La presqu'ile du Sinai, Bibliothèque de l'Ecole Pratique des Hautes Etudes* 171.
15. Rehder, J. E. (2000). *The Mastery and Uses of Fire in Antiquity*. Quebec.
16. Scheel, B. (1989). Egyptian Metalworking and Tools. *Shire Egyptology* 13, 22.
17. Seyfried, K.-J. (1981). *Beiträge zu den Expeditionen des Mittleren Reiches in die Ost-Wüste*, HÄB 15. Hildesheim.
18. Tylecote, R. F. & Boydell, P. J. (1978). Experiments on Copper Smelting Based on Early Furnaces Found at Timna. In B. Rothenberg (ed.), *Chalcolithic Copper Smelting: Excavations and Experiments*, *IAMS* 1, 28.
19. Tylecote, R. F. (1981). From Pot Bellows to Tuyeres. *Levant* 13, 111.
20. Verly, G. et al. (2022). Minerais arséniés et production d'alliages de cuivre. *Archéologie expérimentale des matériaux associés aux productions métalliques: (re)mettre la science en culture*. s.l., international workshop, 19–40.