

# ENKI & PTAH

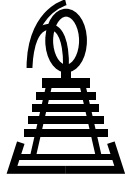
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in Ancient Egypt and Western Asia

Vol. 1 / 2025



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# ENKI & PTAH

Journal of Technology and Trade  
in Ancient Egypt and Western Asia

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## Editorial

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It is with great pleasure that we introduce the first issue of *Enki & Ptah. Journal of Technology and Trade in Ancient Egypt and Western Asia*, a new peer-reviewed scientific publication dedicated to the study of technology, scientific knowledge, crafts, exchange in the ancient societies of Egypt, Nubia, the Eastern Mediterranean and Western Asia. Ranging from prehistory to the Hellenistic and Roman periods, the journal offers an interdisciplinary platform for exploring the material foundations of ancient economies and the cultural dynamics that shaped them. *Enki & Ptah* was conceived with the ambition to bring together complementary perspectives from archaeology, history, and philology, and to foster a cross-regional and diachronic approach to the study of ancient technologies and exchange interactions. By placing Egypt, the Eastern Mediterranean and South-Western Asia within a shared analytical framework, the journal highlights the interconnected worlds of technological innovation, craft specialisation and long-distance trade, and the many ways in which these shaped social and economic structures over time. Rooted in the long-standing Italian tradition of Egyptology and Near Eastern studies, the journal aims to serve as an intellectual meeting ground for scholars

investigating the technological, economic and social dynamics of pre-modern cultures, while also fostering methodological innovation and new interpretative frameworks. Its scope embraces a broad thematic and chronological range, inviting contributions on raw-material procurement and processing, production and distribution systems, archaeometric and scientific analyses, as well as textual and iconographic sources on technology and know-how. Particular value is placed on studies that illuminate the transmission of technical knowledge across regions or periods, or that explore the relationship between innovation, environment, agency and local traditions. A defining feature of *Enki & Ptah* is its commitment to interdisciplinary dialogue. The journal encourages the integration of archaeological, scientific and textual evidence, offering a space in which methodological reflection and theoretical perspectives can inform new understandings of ancient technologies and economies. We especially welcome research that challenges disciplinary boundaries or proposes innovative approaches to the study of craft practices and exchange networks. Co-directed by its editors together with a dynamic board of early-career researchers from the University of Milan, *Enki & Ptah* adopts a double-blind peer-review

system and benefits from the guidance of an international scientific committee composed of leading specialists in Egyptology, Assyriology, and the history and archaeology of ancient Western Asia. The journal consists of a section of research articles and a section dedicated to reviews of recent volumes relevant to its areas of interest. Published by the Milano University Press in open access, with print-on-demand options, *Enki & Ptah* reflects the University of Milan's commitment to fostering high-quality, accessible and interdisciplinary research, according to the FAIR principles. This first issue opens with a substantial collaborative article by a team of scholars from the Centre of Excellence in Ancient Near Eastern Empires at the University of Helsinki. Their contribution offers a far-reaching comparative analysis of the relationship between kingship and economic structures in ancient Western Asia, a field of research that has recently experienced a notable revival, enriched by new methodological perspectives. The article presents a systematic diachronic comparison spanning more than a millennium, examining the economic foundations of kingship and, to a lesser extent, queenship, across seven major empires (Neo-Assyrian, Neo-Babylonian, Teispid-Achaemenid, Seleucid, Ptolemaic, Arsacid and Roman). Particular attention is given to the distinction between "state" and "royal" assets and expenditures, explored here to an unprecedented degree. Massimo Maiocchi's article addresses the methodological and historiographical challenges surrounding the study of the earliest writing systems of south-western Asia and northern Africa: proto-cuneiform, proto-hieroglyphic and proto-Elamite. A reassessment of the scholarly debate reveals persistent disciplinary biases and the modern prestige attributed to literacy, which have long

shaped narratives that overstate writing as the primary marker of civilisation. By exposing these ideological assumptions, the study advocates for a more balanced interpretive framework that situates the origins of writing within the broader cultural, technological and social dynamics of the late 4<sup>th</sup> millennium BCE. The contribution by Padovani and Zingarello examines the mechanisms of control and management of ceramic production during the late Early Bronze Age in northern Mesopotamia, adopting an explicitly archaeological perspective grounded in the analysis of manufacturing contexts, particularly in light of recent discoveries in Iraqi Kurdistan. Focusing on the site of Logardan, the authors present newly uncovered workshops equipped with large and technically sophisticated firing installations. Drawing on fresh spatial, architectural and technological data from ongoing excavations, the study reassesses longstanding assumptions about the political, technical and socio-economic dimensions of pottery manufacture under the first empires of the 3<sup>rd</sup> millennium BCE, highlighting an incipient trajectory towards proto-industrialisation. Ilaria Sieli's article investigates the relationships between Lower Nubia and Egypt through the analysis of three cemeteries belonging to different phases of the A-Horizon, the earliest cultural horizon of the region. By tracing changes in funerary customs and their implications for Nubian society, and by emphasising regional distinctions within Lower Nubia, the study highlights episodes of contact, tension and divergence with Egypt, as well as instances of creolisation that made Lower Nubia a key interface between distinct cultural spheres. The final contribution, by Ahmed Mansour, turns to the emerging field of ancient Egyptian metallurgy. Despite numerous scientific analyses on metal

composition and technology, our understanding of early manufacturing processes and working conditions remains fragmentary. By examining the written evidence that accompanies Old Kingdom metallurgical scenes, the article integrates textual and visual data to clarify technical procedures, operational stages and the demanding working environment of ancient metalworkers. Together, these sources offer a more accurate and coherent reconstruction of one of Egypt's most specialised industries.


As this inaugural issue brings together diverse perspectives on handicraft production, exchange, and economic systems across ancient societies, we invite our readers and contributors to join us in a shared space where new findings, approaches and ideas may converge, shedding fresh light on the complex interactions and cultural meanings that shaped the procurement, transformation and circulation of materials and products in ancient Egypt and Western Asia.





# Decoding Ancient Egyptian Metalworking: A Textual Analysis of Old Kingdom Iconography

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## Abstract

*The study of ancient Egyptian metallurgy is an emerging field. While hundreds of analyses of the chemical composition and technology of metal objects have been conducted, there is incomplete knowledge about the techniques, manufacturing processes, and working conditions of the early metalworkers in the region. The metalworking scenes in ancient Egypt, are, on one hand, informative, since they depict several stages of metalworking, from the weighing of crude metal to the production of metal sheets for the fabrication of vessels. On the other hand, the accompanying texts delve into critical aspects of the depicted activities, offering valuable insights into technical details. This paper examines the texts accompanying the metalworking scenes from the Old Kingdom to offer a clearer understanding of the various stages in the metalworking process, the technical treatment involved, and the working conditions in one of the most demanding industries of ancient Egypt. It will also cross-reference visual depictions with existing textual sources to assess the accuracy and depth of knowledge regarding metalworking practices.*

**Keywords:** Accompanying texts, Workshop scenes, Metalworking, Metals, Old Kingdom tombs, Vernacular language, Ancient Egyptian metallurgy

## 1. Introduction

Ancient Egyptians were neither the inventors of metallurgy practices nor the most innovative in its development. However, metals, particularly copper and gold, held significant importance in their culture (Odler 2021). The tomb paintings and reliefs of ancient Egypt, even if created within a specific funerary context and reflecting particular religious purposes, nonetheless serve as a significant source of evidence for reconstructing the history and culture of ancient Egyptian society. Metalworking scenes are among the areas that have frequently lacked attention. Although influenced by artistic conventions and often stylized, the details

depicted in ancient Egyptian metalworking scenes can offer valuable insights into their methods of production, labor organization, tool design, and usage. When analyzed carefully, these scenes reveal subtle variations that might otherwise go unnoticed – especially in cases where they cannot be confirmed through the archaeological record alone. General surveys, such as those by Petrie, Lucas and Harris, and Nicholson and Shaw, provide some context. In the realm of ancient Egyptian industry-specific monographs, recent studies include analyses of metalworking scenes by Jungst, Scheel, and Davey, as well as commentaries on

specific production aspects by Davey, Altenmüller, Bamberger, Garenne-Marot, Kuhlmann, Odler, Verly, and Hampson. The early studies of the accompanying texts of metalworking scenes in the Old Kingdom are those of Erman et al. (1919) and Montet (1925). Although these works still provide useful information for the understanding of metalworking stages, they are considered out-of-date, because a large quantity of new evidence has provided a more extensive knowledge, as it will be discussed later. The cornerstone of the studies on ancient Egyptian craftsmanship is the work by Drenkhahn (1976) which contains very useful information about metalworking. In addition, Scheel (1985; 1986) published in more elaborated interpretation of metalworking inscriptions. For over four decades, the standard reference on craftsmen in workshop<sup>1</sup> settings has been Rosemarie Drenkhahn's *Die Handwerker und ihre Tätigkeiten im alten Ägypten*. However, her research was focused neither on analyzing how craftsmen were depicted nor conducting a stylistic or chronological breakdown of workshop scenes. Instead, her goal was to shed light on the professional status and social roles of the various occupational groups represented, as well as their work practices, designations, and organizational structures (Odler 2023). Furthermore, much of her analysis has been supplemented or updated by the discovery of over 60 additional scenes since her initial study (Hampson 2022). Recently, Odler (2023) published his encyclopedic monograph on copper in ancient Egypt. The book provides a comprehensive examination of copper's role in ancient Egyptian society across a significant chronological span. It also explores the

use, production, technological development, and significance of copper in ancient Egypt from the prehistoric period through the Pyramid Age and beyond. In addition, Hampson published a detailed study on workshop scenes from Old Kingdom. The first section examines the context, distribution, and tomb placement of the scenes in question. This is followed by a detailed analysis of the scene content, organized alphabetically according to the seven major industries identified in the corpus. A further chapter is devoted to the analysis of all inscriptions pertaining to the scenes and includes a summary of their transcription, application and distribution. Meanwhile, part two consists of a comprehensive catalog that centralizes all research data relevant to the study for the purpose of cross-referencing (Hampson 2022). With the recent publications by Rademakers et al. (2020-2021), Davey (2022), and Hampson (2022), Odler (2023), alongside the ongoing excavations by the French mission at Ayn el-Sukhna on the Red Sea coast (Claire Somaglino and Georges Verly) and the works of the Belgian Archaeological Mission of the Royal Museums of Art and History in Brussels at el-Kab (80 km south of Luxor), it is an ideal moment to consolidate these findings into a unified narrative. Additionally, archeometallurgical research and experimental archaeology offer different insights into the processes of metalworking in ancient Egypt. From 2004 onwards, the Ayn el-Sukhna (Sorbonne University, Ifao, and Suez Canal University Mission) conducted metalworking reconstructions based on experimental archaeology principles to reduce malachite to copper prills. Later, they melted it inside a crucible using

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<sup>1</sup> One of the most valuable sources from the Middle Kingdom is Papyrus Reisner II, a work log from a metalworking workshop dating to the reign of Senusret I. It offers valuable insight into what ancient Egyptians valued in metal objects.

wood charcoal and blowpipes, aiming to produce liquid copper at a temperature of 1200°C. This experiment primarily relied on the metalworking scenes from the tomb of Rekhmire (TT 100, 18<sup>th</sup> Dynasty). However, the experiment did not succeed due to the insufficient information about the process that the scientists gathered from the accompanying texts. This paper analyzes the texts accompanying the metalworking scenes<sup>2</sup> from the Old Kingdom, to provide a clearer understanding of the various phases of metalworking process and technical treatment, along with the working conditions in one of the most challenging industries in ancient Egypt. It will also correlate visual representations with existing textual sources to evaluate the accuracy and depth of knowledge about metalworking practices.<sup>3</sup>

## **2. Metalworking accompanying texts: A quantitative assessment**

The first appearance of a metalworking scenes in the Old Kingdom can be observed in the 4<sup>th</sup> Dynasty in Giza. The tombs of Khuenra (MQ 1), Meresankh III (G 7530-7540) and Nebemakhet (G 8172 and Lepsius 12) show for the first time metalworkers in two-dimensional

representation. Nevertheless, such scenes were devoid of any texts. The remarkable inquiry when studying the metalworking accompanying texts is their occurrence during the Old Kingdom. It is important to clarify the reason for choosing the Old Kingdom period. Unlike the metalworking scenes from the New Kingdom, those from the Old Kingdom include significant technical details and accompanying texts. Examining these scenes and their texts is essential for understanding the development and continuity of metalworking practices over time, as well as their impact on technological advancements. These scenes reflect techniques that differ from those used in the New Kingdom. In a recent article, Motte (2021) examined the speech genres of daily life scenes in the Old Kingdom as part of his PhD research. He concentrated on defining the identity of these speech genres by addressing three key aspects: the mode, which relates to the rhetorical dimension; the themes, which pertain to the space-time framework and recurring patterns; and finally, the forms, which explore the interplay between the first two axes (Motte 2021: 296). The analysis of metalworking texts is based on representations from 32 tombs of the Old Kingdom.<sup>4</sup> Through a detailed analysis

<sup>2</sup> I had personal communication with Christopher Davey in 2014-2015, during which he mentioned that he was preparing to publish and comment on the metalworking texts from the Old Kingdom. However, this work was never published.

<sup>3</sup> This paper is extracted from my PhD thesis *Metalworking Scenes during the Old and Middle Kingdoms: A Linguistic, Iconographic and Analytical Study*, Faculty of Tourism & Hotels Department of Guidance Alexandria University (2016).

<sup>4</sup> In the last two decades the compilation of material has been acknowledged as a vital research tool by the Universities of Oxford and Leiden, along with the Museum of Fine Arts, Boston. This recognition has led to the development of prominent online platforms such as The Oxford Expedition to Egypt Scene Details Database, MastaBase, and The Giza Archives. The author utilized the Oxford Expedition to Egypt Database (OEE) to compile a list of tombs featuring metalworking scenes. Altogether, 37 metalworking scenes have been discovered, depicting the processing of gold, silver, electrum, and copper, as well as other unspecified metals. The most recent of the tomb of Ptahshepses at Saqqara. Additionally, a metallurgical scene in the tomb of the funerary priest Wahty at Saqqara is yet to be published. The author then turned to The Leiden MastaBase to gather essential statistics, aiming to better understand the significance of these scenes in the decoration programs of Old Kingdom tombs. It is worth noting that the author benefited from the Leiden MastaBase when it was initially published as a CD, and it is now available online.

of the texts during the Old Kingdom (Fig. 1), it has been noted that throughout that period metalworking scenes include 61 texts in the form of titles, captions, and dialogues. These texts serve to complement the associated imagery by clearly identifying the depicted actions, personnel, or objects. In some instances, they also offer additional technical details about the processes shown, utilizing industry-specific terminology and workshop-specific idioms. The peak of the use of different genres of speech captions in private tombs lie between the mid-5<sup>th</sup> Dynasty to the 6<sup>th</sup> Dynasty (Motte 2021: 299). They are divided into four main categories (Fig. 2):<sup>5</sup>

- Captions: 29.51%
- Damaged: 3.28%
- Names/Titles: 18.03%
- Dialogues (Spoken): 49.18%<sup>6</sup>

The distinction between narrative texts and discourse genres is essential when analyzing metalworking texts in context. These texts align more closely with the discourse genre than with narrative forms. Discourse focuses on active, ongoing communication or instruction, primarily employing the present tense to convey immediacy and relevance. It also frequently utilizes first-person (I/we) or second-person (you) perspectives, emphasizing interaction, directives, and self-reference (Motte 2021: 300). In general, when examining the texts associated with the theme of workshop activities, several key points related to their structure, content, and

purpose would emerge. Firstly, the majority of workshop scenes include inscriptions, appearing in about 75% of the tombs on Old Kingdom. Among these, the most significant texts are dialogues between workers (Hampson 2022).

### 3. Phases of the metalworking process and its accompanying texts

The metal, *i.e.* copper or gold production process involves four main stages: ore procurement and transport, metal storage and transactions, melting and object production, and the use and reuse of artifacts. The most expansive treatments of the industry occur in the tombs of Nebemakhet (LG 86), Mereruka (LS10, Teti Cemetery, PM III, 525-534), Niankhkhnun-Khnumhotep (PM III, 641-644; Hampson 2022). This article focuses on the technical aspects of metalworking as reflected in the accompanying texts and scenes. Below, I will list the texts from each work phase and analyze them to enhance our understanding. The work phases are organized as follows:

#### 3.1. The weighing of the crude metal/metallic objects

Weighing plays a pivotal role in metal production, serving as both the initial and final stage of the process. At the outset, the processed ore or semi-finished product (such as an ingot) is weighed, while at the end, the finished items are weighed before being handed over to the supervising official and

<sup>5</sup> The Leiden MastaBase Project, launched in 1998, created a database of iconographic programs in Old Kingdom elite tombs from the Memphite area (2600-2150 BCE). The MastaBase CD-ROM, released in 2008 and now available for free on Zenodo, provides detailed analysis of themes, their organization, and placement within tombs. It explores variations in tomb art, focusing on regions like Saqqara and Giza, and offers insights into Old Kingdom funerary culture. A user guide is included to assist with navigating the database. More information can be found on the project website.

<sup>6</sup> Regarding the calculations of text occurrence statistics, the database is organized into main themes and subthemes, each with a specific abbreviation. We are focusing on the main theme “trades”, which is abbreviated as TR. Under this theme, the subtheme for metalwork is designated with the abbreviation M. You can have more information. <https://digitalegyptology.org/mastabase/test/>.

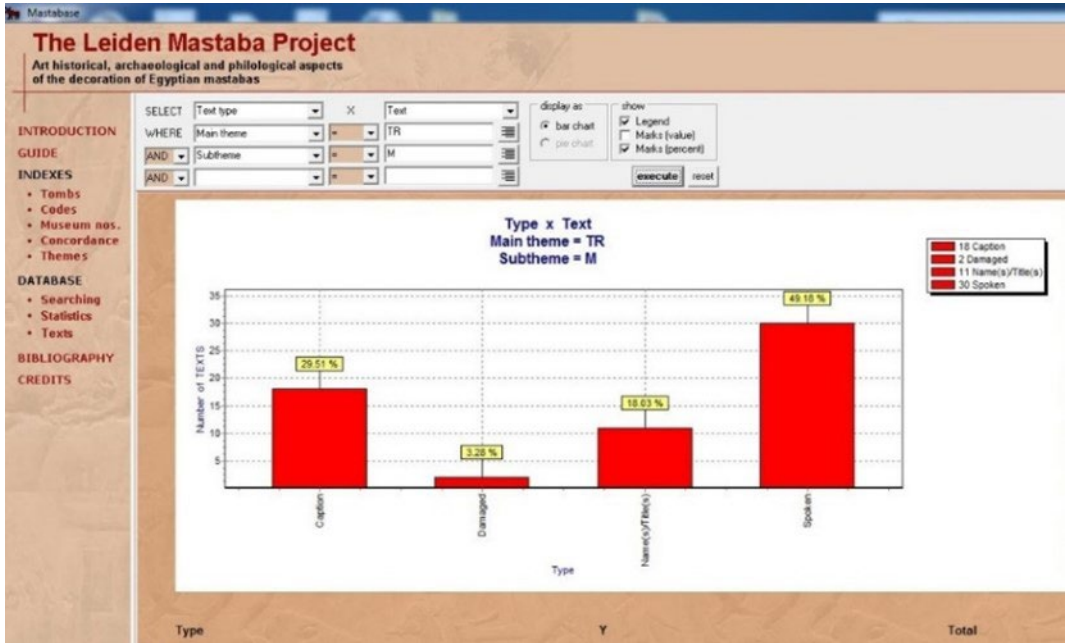


Fig. 1. Distribution of Metalworking text types over Metalworking texts. After the Leiden MastaBase Database.

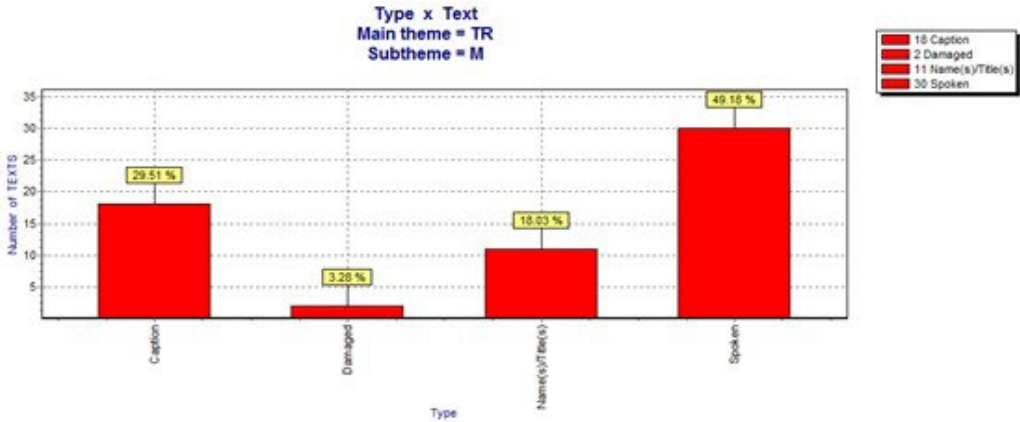


Fig. 2. Statistics were gathered by first selecting the “text type”, which was set to “text”. Next, the user chose “where”, aligning it with the main theme of “TR” (trade themes). Finally, the subtheme was selected as “M” for metalworking.

ultimately delivered to the tomb owner or the treasury (Odler 2023). There are four tombs -Iymery (G 6020, LG, PM III, 170-174), Mereruka (LS10, PM III, 525-534), Ibi (TT 36, PM IV, 243-244), and Senedjemib (G 2378, LG 26, PM III, 87-89) – that feature weighing scenes of the crude metal.

According to Figure 1, the accompanying texts are divided into four main categories: captions, damaged texts, names (titles), and spoken dialogues. The phase of weighing crude metal or metallic objects encompasses all four categories. The metal which is being weighed is designed

as *bi3* ‘metal’, and the weighman which is called ‘*mḥ3ti*’ ‘Weighman’ Mereruka (LS10, PM III, 525-534). Meanwhile, in the tomb of Senedjemib (PM III, 87-89) the text reads: *imy-r3 ... Ffi* ‘The Overseer ... Ffi’. This legend appears between the weighing scene and that of the hammering scene. In the tomb of Ibi (TT 36, PM IV, 243-244), a similar process can be seen in weighing the finished objects. The scene title is *f(3i)t bi3*, ‘Weighing the metal’ (Valbelle 1977). Here, nevertheless, there is no dialogue, but the text reads: *m33 si i(w).s m inr*. It infers that the scale is ‘in weight’ and therefore the weighing process is over. The previous sentence has different interpretations as follows:

- Erman: ‘Check, if it is from stone’ (Erman et al. 1919);
- Montet: ‘Look at it! It is in stone!’ (Montet 1925);
- Kuhlmann: ‘Look at it (*i.e.* the scale)! It is in weight’ (Kuhlmann 1976);
- Scheel gives another interpretation. He suggests that the position of the inscription and the posture of the persons involved in the weighing scene could be interpreted as a call from the overseer who stands to the left of the scale to the weighman who stands to the right. The translation could then read: ‘Check it (the scale) [to see if] it is in weight (if it is in balance)!’. The weighman leans towards the scale at this request, in order to obey the order!’ (Scheel 1985).
- Altenmüller provides a new interpretation. He suggested that the text must be translated as ‘Look at it (*i.e.* the indicator of the scale)! It is on the side of the stone weights’ (*m33 iw.s m inr*) (Altenmüller 1986). The overseer, to

whom it is addressed concerning lack of metal, touches with his hand the string to which the scale-pan with stone weights is attached (Motte 2021: 300). He is checking the correct weight of the stone weights and convinces himself of the preciseness of the scale, his task being now to determine exactly the difference between the weights and the delivered metal and thus to secure the actual height of the shortfall of metal.

- Hampson recently referred to this text as a method of dating. She suggests that the close similarity between these accompanying texts suggests that the artists copied the decorative designs from one tomb to another (Hampson 2022).

However, the significance of this phase lies in the dialogues and exchanges among metalworkers. These conversations are crucial for understanding the working conditions. These dialogues are found in the tombs of Kaemrehu (D 2, S 905, PM III, 485-487) and Mehu (G 2423, PM III, 94). In Kaemrehu a dialogue starts: *n wnt i(w).s n bi3* and the answer *i(w).s m inr*. Kuhlmann suggested that these are vernacular expressions. He interpreted the dialogue as follows (Kuhlmann 1985):

- The left worker: *n wnt iw.s n bi3*, ‘There is no more metal’ as the beginning of the dialogue
- The right worker: *iw.s m inr*, ‘It (*i.e.* the scale *mḥ3t*) is in weight (=it is balanced)’ as the answer.

However, Altenmüller suggested another interpretation. He starts with the right statement (Altenmüller 1986: 7-14).<sup>7</sup>

- *i(w).s m inr*, ‘It (the indicator of the scale) is on the side of the stone weights’ (Valbelle 1977);

<sup>7</sup> He suggests that the expression “*iw.s m inr*” refers to an imbalance in the scale, where the scale pan with stone weights is heavier than the one with metal objects. This causes the scale to tilt toward the side of the weights rather than the metal. Conversely, the expression “*iw.s m inr*” indicates the opposite situation. In this case, the scale is again imbalanced, with the stone weights causing the scale pan to hang lower than the one containing the metal objects. It is worth mentioning that stones are still used for weighing in Egypt today, primarily among villagers and ordinary people.

- *n wnt i(w).s n biꜣ*, ‘Really, it is not in favor of the metal’.
- Hampson translates the last sentence as *iw.s m inr*, ‘It leans to the weight’ (Hampson 2022).

It is noted that the crude metal to be weighed is represented on the left pan of the scale. The person acting on the left of the scale starts the dialogue: ‘There is no more metal!’. His colleague on the right of the scale is filling the right pan of the scale with rectangular stone weights ‘inr’ until it is perfectly balanced.<sup>8</sup> The man engaged in weighing holds an additional stone weight in his left hand, which is unnecessary for achieving balance, as the scale is already ‘in weight’. The weighman informs his colleague saying: ‘It is in weight’. The weighing process is finished and the weighman clearly tells his colleague the number and value of the weighing. His colleague takes note of the result. According to Altenmüller (1986), the result of the weighing process is not in the side of the metalworker. This can be inferred because of a detail of the representation of the weighing man. He holds a stone weight in his free hand which he has taken from the pan with the weights (that in a previous moment hung lower). In other words, he is trying to determine exactly how much metal is missing. If he were to put the stone weight he is holding on the scale again, it would show the deficit in metal.

In the tomb of Mehu (G 2423, PM III, 94), the weighman addresses his speech to the overseer of metalworkers. The dialogue reads: *fꜣ nw r mꜣꜣ hr-tp mhꜣt*, ‘O overseer, weigh this correctly!’ (Hampson 2022);<sup>9</sup> *iw s ni Mnw hr mhꜣt*, ‘The ‘Senmenu’ is on the scale!’. The dialogue is structured in two distinct parts:

- The first part*: It contains an instruction directed at the overseer of the metalworkers, emphasizing the need to carefully measure the discrepancy between the amount of metal delivered and the amount returned. The order stresses that this measurement should be fairly conducted, ensuring that the weighing process remains unaffected by any external influence.
- The second part*: It addresses an issue related to the imbalance of the scales. It deals with the concerns or discrepancies regarding the accuracy of the balance used for weighing the metal, highlighting the need to address and rectify any inconsistencies in the weighing equipment. Finally, the lack of some metal is recorded by the scribe. He is the ‘Judge and scribe Baefba’ in office. His duty as officer is explained as the text reads *sꜣ m fꜣit biꜣ* ‘Writing down (the result) of metal weighing’ (Altenmüller 1986; Piacentini 2002).<sup>10</sup>

<sup>8</sup> Odler (2023) proposed that the rectangular weighing stones, used as a determinative for concepts related to weighing, depicted in Old Kingdom metalworking scenes be identified as *dbn*. This term refers both to the unit of measurement associated with these stones and to the objects themselves, crafted by artisans. Furthermore, the shapes of semi-finished metal products – such as rings, coils, or spirals – can be inferred from the semantic associations of the term *dbn*. Moreover, Odler noted that silver bracelets from the burial equipment of Queen Hetepheres were referred to as *dbnw*, and the term ‘Craftsman of Deben’ was mentioned in the tomb of Nyankhkhnum and Khnumhotep as a circumstantial designation rather than a full-time category of Old Kingdom craftsmen (Odler 2023).

<sup>9</sup> Hampson mentioned that the scribe used an adverb to indicate that the expectations regarding quality have been satisfied.

<sup>10</sup> Mehu held the highest positions in administrative, priestly, and judicial fields during the 6<sup>th</sup> Dynasty. Several scribes were also part of this prominent family’s staff. In his tomb, some scribes are depicted as bearers of offerings, while one is shown in the traditional scene of weighing the ingots.

### 3.2. The Melting Process of the Metal

The accompanying texts of melting scenes provided a more detailed description of the melting process itself, specifically referencing the metals intended to be melted such as *bīz*, ‘metal/copper’<sup>11</sup> or *ḏ<sup>c</sup>m*, ‘Electrum’. The action of melting is expressed as: *nbit bīz*, ‘Melting metal’ and *nbit ḏ<sup>c</sup>m*, ‘Melting electrum’. Gold and silver are heated, as it is expressed by *fst nbw*, ‘Heating of gold’ and *fst ḥḏ-nbw*, ‘Heating of silver’. Similarly to the weighing phase, the four categories of accompanying texts were also present in the melting process, offering a detailed and comprehensive overview of the entire procedure, as it follows:

#### a) *Melting process*

The melting scene is a common feature in the majority of tombs within the metalworking scenes, serving as the standard representation of the industry. This aligns with its role as the foundational stage preceding all other phases of production. Its consistent inclusion is further highlighted in the tombs of Mehu (G 2423, PM III, 94) and Kagemni (LS 10); where it was chosen for decoration despite spatial constraints

(Hampson 2022). After the weighing phase, the crude metal<sup>12</sup> was placed in a crucible and set over the fire. The metalworkers were then required to blow air with considerable force into the charcoal under the crucible, in order to melt the metal prills.<sup>13</sup> The notable accompanying texts of the melting process are found on the wall tombs of Mereruka (LS10, PM III, 525-534), Iymery (G 6020, LG, PM III, 170-174), Ankhmahor (PM III, 512-515), and Hem-re (PM IV, 243) presented as dialogues between the metalworkers. The accompanying text “*ds m3 pw s3ḥ mndwt.f nti ḥn<sup>c</sup>.i*” in the tomb of Mereruka (LS10, PM III, 525-534) is identical in meaning to “*wḏi r tḥwt.f ds m3 pw*” in the tomb of Iymery (G 6020, LG, PM III, 170-174). In both statements, there is a request to blow air into the crucible, as it is new and the metal inside requires further work to be melted. The different modes of expression for the same content may reflect variations across historical periods, with the tomb of Iymery (G 6020, LG, PM III, 170-174) dating to the 5<sup>th</sup> Dynasty and that of Mereruka (LS10, PM III, 525-534) to the 6<sup>th</sup> Dynasty (Forbes 1972; Weinstein 1974).<sup>14</sup> According to Davey, the sentence *ds m3 pw* should be interpreted as: ‘It is a new

<sup>11</sup> The widespread use of arsenical copper in Old Kingdom Egypt is well-documented, with evidence of its presence at nearly all Egyptian sites. This suggests that either the copper came from arsenic-rich ore deposits or arsenic was intentionally introduced during processing (Odler 2023). Arsenical copper was favored for its silver-like sheen, making it a luxury item in ancient Near Eastern cultures, including Egypt (Chen 2021).

<sup>12</sup> I should clarify that smelting metal refers to the process of extracting metal from its ore by heating and melting (reduction process), while melting metal refers to the process of heating metal until it becomes liquid (refining process). The metalworking scenes represent only the melting process, not the smelting process. This means that the ancient Egyptian artist depicted the initial phase, such as weighing the crude metal, but omitted the smelting process in order to showcase the melting process using blowpipes and crucibles.

<sup>13</sup> Copper prills, common in production and often alloyed in crucibles, lack a specific name in texts. The plural sign of three small circles may reflect their droplet-like shape, with the term *nws* from Amenemhat II’s annals being a potential designation (Odler 2023).

<sup>14</sup> The sentence ‘*nbt biA wḏi r tḥwt.f ds m3 pw*’ is used by Forbes (Forbes 1972) erroneously interpreted as: ‘It is molten, knock hard at its bottom, here is a new pot!’, which probably means that copper has been melted and the foreman is summoned to thrust open the clay stopper at the bottom of the melting pot to let the copper flow into a new pot.

crucible'. It is commonly observed in metalworking scenes. It is typically used when a new crucible or pot is employed for the first time. During its initial use, a substantial amount of extra heat is required to initiate and sustain the endothermic reactions within the ceramic material (Barsoum 2003).<sup>15</sup> This is necessary as the pot is heated to approximately 1100°C for the first time, ensuring that it can effectively handle the high temperatures needed for metalworking processes. Therefore, the expression serves as a directive to increase effort from the blowpipers during this critical initial phase, highlighting the importance of their role in managing the extra energy needed (Davey 2011: 25-36). Similarly, in the tomb of Iymery (G 6020, LG, PM III, 170-174), it reads: *wḏi r tbt.f ds m3 pw* Give to its bottom,<sup>16</sup> mate, it is a new crucible!'. Therefore, it is understood that air or oxygen should be blown to the bottom of a new crucible in order to raise the temperature. To stress this point the metalworker used *ds m3 pw*, 'It is a new crucible!'.<sup>17</sup> The word *ds*, 'Jug' (*Wb* V) can therefore be directly seen as a synonym for *bḏt*, 'crucible'. In the tomb of Ankhmahor (PM III, 512-515), the statement occurs, but it is presented in the form of a dialogue: worker 1: *m33 ḥr.f ds m3 pw* 'Look at it, it is a new crucible' (*wḏi m tbt.f wrt nt(y) ḥn<sup>c</sup>.(i) ḥn.k m ḥnḥ* 'Give well to its bottom, mate, as much as possible', meanwhile, worker 2 *Iri r ḥst.k m33* 'Yes, Sir!' Similarly, in the tomb of Hem-re (PM IV, 243), the text reads: '*wḏi r kbwt ds m3 pw wni.kw r ḥr nfr*'. Scheel suggests interpreting it as 'Give to the bottom, it is a new crucible; hurry up to the beautiful face!'. The second part *s3ḥ mndt* along with the

term *mndt* warrants a thorough examination, as various interpretations have emerged in scholarly discourse. Previous interpretations of *mndt* have ranged from "crucible wall" to "pouring out the hole of the crucible" (Montet 1925; Drenkhahn 1976; Hampson 2022), "melting mass" (Moussa and Altenmüller 1977), "nasal-hole" (Erman et al. 1919), and "cheek/wall" (Westendorf 1961; Meeks 1977). If 'cheek' is seen as a metaphor, surely right, for 'wall' ('crucible wall'), then *s3ḥ mndwt.f ntḥ ḥn<sup>c</sup>.i* should be translated in this case as: "Come (close) to its walls, mate!" (Grapow 1960). Similarly, Hampson interprets it as "Reach its cheeks, comrade!", describing the outer walls of the crucible as "cheeks" in the context of workshop terminology (Hampson 2022). Grapow suggested that *mnDt* should be understood metaphorically, similar to the expression *ḥr nfr*, which describes the shiny appearance of molten metal within the crucible (see below). This metaphorical interpretation encouraged a deeper exploration of the term's significance beyond its literal meanings. *i.e.* the melting operation. To achieve an accurate interpretation of *mndt*, it is crucial to consider the specific context in which it appears, particularly during the melting operation. The nuances of the melting process, including the physical characteristics of the materials and the environmental conditions involved, can inform our understanding of how *mndt* is interpreted. It is known that the temperature of burning charcoal increases with the intensity of breath; thus, blowpipe nozzles were designed with small apertures to maximize air velocity. However, this restriction in the air jet limited the area of the fire being ventilated. Consequently, the

<sup>15</sup> The endothermic reactions within the ceramic material refer to processes that absorb heat during chemical reactions.

<sup>16</sup> Hampson translates it as: "Place at its sole".

<sup>17</sup> With this is obviously meant that air must be blown on the charcoal lying on the bottom of the crucible, so that the hearth goes up more quickly.

expression likely serves as an instruction to direct the blowpipe at the small opening above the temporary barrier, allowing the breath to effectively ventilate the fire inside the crucible, just above the molten metal. Therefore, a translation such as: “Point (the blowpipe) at the gap (above the barrier)” seems plausible (Grapow 1960). Drenkhahn suggested the translation as follows: “Touch this pouring hole!”. The equivalence of the crucible walls with the pouring hole must nonetheless be doubted, since the blowing by the six melters<sup>18</sup> (in Mereruka tomb LS10, PM III, 525-534) around the crucible walls is much more effective for the melting process than it would be blowing air to the pouring hole (Davey 2009: 37-46).<sup>19</sup>

b) *The expression nfr hr/hr nfr ‘Beautiful Face’*

It is important to discuss here the expression *nfr hr/hr nfr*, meaning ‘Beautiful face’. The expression literally means ‘beautiful face’, but it serves as a metaphor, generally thought to refer to the bright color of the molten metal’s surface (Hampson 2022). This suggests that the phrase encourages the metalworker to act quickly with the molten metal to prevent it from freezing (Davey 2011: 25-36). Scheel further elaborates on this point, suggesting that the crucible and its contents were metaphorically perceived by the melters as real individuals (Scheel 1985). They noted that the surface of the molten metal – its ‘face’ – became ‘beautiful’, indicating that its appearance was favorable.

This transformation signified that the metal was ready for further work, thus indicating that the melters had successfully completed their task (Edel 1955). This example illustrates how language in ancient Egyptian texts not only conveys practical and technical information but also enriches the narrative surrounding the melting process, imbuing it with human qualities and emotions. In this context, it is easy to imagine that the melters may have referred to the filled crucible itself as a ‘head’.<sup>20</sup> This personification further highlights the close relationship between the metalworker and the crucible, underscoring the crucible’s vital role in the transformative process of metallurgy. Therefore, the melters needed to observe the crucible closely to determine the precise moment when the metal begins to liquefy. A text reads: *wni.tw wrt r hr nfr I phr m bd*, ‘Be quick, mate! (my fellow worker), hey, stir well in the crucible!’. The metalworkers were asked to blow more intensively into the hearth, in order to reach the melting point. Such text highlights different aspects of performance, including speed, efficiency, teamwork, and quality production. For example, the emphasis on rapid task completion is most clearly demonstrated by the repeated use of the directive “Hurry!”, conveyed in the form *wni.tw* (Hampson 2022). In the same time, after the liquefying phase, it is necessary to stir the metal properly in the crucible. According to Drenkhahn (Drenkhahn 1976), the stirring doesn’t mean to mix crude metal with

<sup>18</sup> Estimated groups of the metalworkers comprised ten men, within it also their supervisors.

<sup>19</sup> Indeed, the crucible shape in Mereruka tomb was designed to concentrate heat, conserve charcoal, and facilitate pouring molten metal. This design likely evolved into the crucibles of the First Intermediate Period and Middle Kingdom, retaining the front hole but featuring a bowl-shaped base.

<sup>20</sup> Regarding the use of the word “head”, Grapow suggests a connection between *‘d3d3’* (head) and *‘d3d3w’* (pottery container) (*Wb V*). This implies that a bowl or crucible can symbolically represent one another. Additionally, the crucible often has a rounded shape reminiscent of a head (Curto 1962; Forbes 1972). Consequently, the contents of the crucible, which the metalworkers observe during their process, can be viewed as the “face”, while the walls of the crucible represent the ‘cheeks’ of this metaphorical face.

the rest, in order to speed up the melting process. More probably, according to Scheel, the ‘Stirring of the molten metal’ (with a wooden stick) is a procedure of refining, by which specific elements loosely present in the molten metal should evaporate or be modified (Scheel 1985). An accompanying text, in the tombs of Iymery (G 6020, LG, PM III, 170-174) and Senedjemib (PM III, 87-89), reads *sk phr mnḥ* ‘Hey, mix/stir properly!’ which serves as a directive for refining the molten metal (Scheel 1985). According to Hampson, these texts strongly prioritize the importance of completing tasks swiftly and effectively, presenting efficiency as a key objective (Hampson 2022). A relevant statement appears in the tomb of Niankhkhnun and Khnumhotep (PM III, 641-644), which reads: *šmšm tꜣw ḥr sn.f wꜣ mndt im ndrꜣw* (Hampson 2022). The first part reads: *šmšm tꜣw ḥr sn.f* ‘The air is hot due to its brother’ (Altenmüller 1984), ‘The air is hot because of breathing’ (Hampson 2022). This part is attested, also, in two other tombs, both dating to the 5<sup>th</sup> Dynasty: Ptahshepses in Abusir, and that of Kaemrehu (D2; PM III, 486 [2]) in Saqqara. The second part of the statement *wꜣ(i) mndt im ndrꜣw* should be interpreted: ‘The walls of the crucible glow, do not touch!’ *wꜣi* would therefore be translated with the meaning of ‘To dry’, (*Wb* I) where the *Wörterbuch* refers to *wꜣ* ‘Embers’. Possible synonyms to ‘Dry’ are, among others, ‘Roast’, ‘Simmer/Carbonize at low temperature’, ‘Burn’ and ‘Glow’, so that *wꜣi* can surely be translated as ‘Glow’. *Ndrꜣi* has to be translated in its original meaning of ‘hold’ or ‘touch’. (*Wb* II). The text asserts that the metal’s liquefied state is most distinctly depicted by a figure leaning or bending toward the furnace while holding a rod or stick. This tool is used to maintain the flame’s intensity and stir the molten metal (Hampson 2022). In summary, the melting scenes typically

feature interactions among colleagues, often involving directives aimed at ensuring the work is performed flawlessly. Control over the fire in metalworking was more effectively achieved using blowpipes rather than pot-bellows, which were heavier and less commonly employed. While bellows, especially when used with tuyeres, were better suited for larger fires requiring a more general application of heat, blowpipes provided greater precision in blaze control. However, the efficiency of blowpipes came with a drawback: the physical effort needed to operate limited the duration for which a worker could use them continuously. Thus, blowpipes were preferred for their control and precision, despite the physical strain they placed on the operator (Davey 2011: 25-36).

### c) *The pouring of molten metal*

There is one unique inscription describing the pouring of the molten metal. It occurs in the tomb of Wepemnefret (PM III, 281-282) *wdḥ biꜣ*, ‘Pouring of the metal’. It describes the scene itself. The pouring action is marked by a high level of standardization in the scenes corpus. Most examples typically feature the bending of the back and the holding of the crucible by its sides, with some variations showing the inner elbow raised to illustrate the turning motion of the arm as the crucible is emptied (Hampson 2022). As mentioned above, the molten metal should be of ‘Beautiful face’, *i.e.* liquid enough to be poured. This stage is expressed by *iw nfr ḥr ir wrt*, ‘The face is beautiful, very much’ The metaphor appears in the inscriptions of the melting scenes and has been explained extensively in that section. A rare evidence is the depiction of cooling molten/casted metal by dousing it with water, which occurs in the tomb of Pepyankh (PM IV, 125-126). A text reads: *di hꜣi nšnw ḥr skbb* (Edel 1955).

According to Scheel, it could be translated ‘Give, that the vessel part rises up in order to cool it!’. Another suggestion for translation, according to Kanawati, is “Put the material down that it cools: (Kanawati 2014), or ‘Let the liquid go down on it to be cool!’ (Hampson 2022). The metalworker asks his colleague to rise up and put down the crucible in order to cool it, so that they can handle it. The answer is given by the seated metalworker: *iry.i ir hst.k*, ‘Yes, Sir’ or ‘I am acting according to your praise’. The metalworker had evidently to fasten or to oversee the cooling down of the molten metal (by moistening it with water?; Scheel 1985). This particular formula appears in the metalworking accompanying texts, expressing a positive response to specific orders or calls. In the tombs of Mehu (G 2423, PM III, 94) and Ankhmahor (PM III, 512-515), it reads: *iry.i ir hst.k*, ‘I am acting according to your praise’ (Erman et al. 1919; Montet 1925). In terms of meaning, this call is most accurately translated as “Yes, sir!”. Projecting the Western view onto Egyptian genres would inevitably lead to misunderstanding(s), since each epoch has its own system of genres. Indeed, the dialogues of metalworkers are still reflected in colloquial Egyptian. For example, the master is always giving instructions to his pupils, directing them to the adequate process of fulfilling their tasks. The previous sentence can be understood in the frame of colloquial Egyptian “*Iri.t hr hst.k*” “Yes, sir”, «يـمـلـعـم اي رضاح».

An interesting detail shows the use of pads to carry the burning metal pots. Indeed, the use of insulating pads to carry the crucible, thought to be made of wood, stone, or clay, is a detail found only in Memphite tombs. Without the use of

holding pads, the hands are positioned flat against the crucible to represent the cupping action, even though this does not reflect the actual process.<sup>21</sup> Usually, crucibles were made from a refractory and insulating but weak ceramic, new crucibles were fired lightly to about 700°C or were made from a thicker sun-dried clay. The creation and operation of these crucibles required expertise and skillful manipulation, which must have been acquired from by a well-defined craft tradition. That tradition appears to be depicted in several Old Kingdom tomb reliefs. During the reconstruction experiment of melting copper prills at Ayn Sukhna site, by the French mission, the craftsmen used plant reeds to carry the crucible. Moreover, the angle of pouring may indicate specific technical and regional variations. The vertical pouring position, found at Giza (Wepemnefret PM 282 [6]), suggests a relatively high level for pouring such hot liquid. In contrast, the curved flow is a distinctive feature of tombs at Saqqara, such as that of Mereruka. The height from which the metal was poured seem to have been exaggerated, for artistic purposes (Hampson 2022). Davey mentioned that the craftsmen used sticks to remove the impurities of melting action. This is confirmed by the depiction of such process on tomb walls. The use of a stick to hold back impurities in the molten material and to regulate the flow is uniquely illustrated in the tomb of Mereruka (LS10, PM III, 525-534). The size and shape of the crucible and mold depicted in the pouring scenes support Davey’s argument that this procedure was necessary for casting a larger volume of material. Moreover, the tomb scenes reveal that molten metal was not

<sup>21</sup>Crucibles were typically made from a refractory, insulating, but fragile ceramic. New crucibles were either lightly fired to about 700°C or crafted from thicker sun-dried clay. Their creation and use demanded expertise and skill, likely developed within a well-established craft tradition, which is depicted in several Old Kingdom tomb reliefs (Davey and Hayes 2023: 13-14).

poured into a mold but onto a flat surface, where it flowed out and was hammered as it cooled to form a sheet approximately 20 cm in diameter and 1.5 mm thick (Davey and Hayes 2023: 17).

#### d) *The hammering/beating of metal foil*

Like the previous inscriptions, the hammering/beating scenes also include inscriptions that label the activity: ‘Beating or hammering foils (metal sheet)’. These inscriptions were short and conveyed easily comprehensible statements. For example, on the Unis causeway, the inscriptions in the tombs of Mereruka (LS10, PM III, 525-534) and Mehu (G 2423, PM III, 94) each read as it follows: *skr dꜣm*, ‘Beating the Electrum’. The molten metal was shaped by beating it with round or ovoid hammer stones and using anvils made of metal, stone, or wood. Three common lower body postures are depicted for the beating action: squatting, kneeling, or sitting with knees drawn up. These postures are shown with various arm positions (Hampson 2022).

### 4. The work circumstances

#### 4.1. *Dry and hot environment*

Due to the challenging working conditions, the workers sought to drink liquids to endure the hot air. The text in the tomb of Kaemrehu (D 2, PM III, 485-487) reads: *hnkt(n)skr it*, which translates to ‘Beer of Sokar, prince/mate.’ This response reflects the intense circumstances under which the melting process took place, characterized by strenuous work and the hot breeze from the hearth. The metalworkers requested their overseer to provide them with refreshing beer, specifically the beer of Sokar (Helck 1971). The reference to the god Sokar is not surprising, as Sokar is associated with Ptah (Roccati 1982), the patron of craftsmen

and artists, making him also responsible for all metalworkers. Additionally, the domain of Sokar, the deity revered by metalworkers, extended beyond copper and gold to include iron – particularly celestial iron and copper derived from stars and meteorites (Odler 2023). Another statement connects Sokar to the metalworkers. An inscription from the tomb of Djadjaemankh (PM III, 483-484) reads: *hw(i) hmsw n skr hmww pw* (Erman et al. 1919; Montet 1925; Hodjash and Berlev 1982; Altenmüller 1984: 7-14). Scheel interprets it, albeit with some reservations, as: “Ah, that there were no faults for/in Sokar, oh, these craft (these arts)!” (Scheel 1985). This statement can be seen as an appeal from the metalworker, lamenting that there can be no rest or errors in the service of Sokar. Meanwhile, Hampson translates it as “Drive off sloth for Sokar, this craftsman!”. This suggests that invocation was a prevalent feature of the workshop vernacular (Hampson 2022).

#### 4.2. *Fatigue and burden work*

One interesting detail in the metalworking accompanying texts is that metalworkers often expressed their fatigue from the intense and laborious work involving high temperatures. For instance, in the tomb of Mehu (G 2423, PM III, 94), the text reflects the challenges and exhaustion faced by these workers, highlighting the demanding nature of their craft. It reads: *iw.(i) wrd.kz(i) hr kst m pr m hnk.i*, ‘I am tired due to the work in the house of my friend’. Motte noted that these speech captions emphasize the workers’ bravery and sacrifice. (Motte 2021: 303). Meanwhile, Hampson interprets this statement as a requirement for prompt action to meet a production deadline, as demonstrated in a conversation between the two stringers. It indirectly highlights how expectations for the swift completion of tasks are communicated. (Hampson 2022).

### 4.3. Motivation to work properly and teamwork

According to Hampson, references to teamwork, both explicit and implicit, frequently appear in the inscriptions. These include workmen addressing each other affectionately with terms like *sn* ‘brother’, *mry* ‘my dear’, or *hn<sup>c</sup>.i* ‘comrade’, or instances where a partnership between them can be inferred (Hampson 2022). Different requests to improve work quality were found. For example, in the tomb of Mehu (G 2423, PM III, 94) the text reads: *h3(i) ir.k nti hn<sup>c</sup>.i*, ‘Fall down, mate!’ (Moussa and Altenmüller 1977); ‘O, come down, comrade!’ (Hampson 2022). It is a request to hit very hard on the metal foil in order to flatten it well. Various requests aimed at improving work quality have been identified. For instance, in the tomb of Mehu (G 2423, PM III, 94), the text reads: *ih3i in.(i)*, ‘Fall down, and bring!’, where *ini* serves as a support for the request. The worker to whom the speech is addressed answers to the call: *ini.(i) hm* (Edel 1955), ‘assuredly, I will come on!’. In addition, direct requests to *skr*, ‘Beat the foil can be found in the tombs of Ptahshepses (PM III, 460-461) and Ibi (PM IV, 243-244). The call in the tomb of Ptahshepses (PM III, 460-461) reads: *skr wrt n ...*, ‘Beat hard, not/without ...!’ (Erman et al. 1919; Montet, 1925), and *skr ir(i) m p3kt* ‘Beat, make (it) a foil/a sheet metal!’ (Erman et al. 1919; Montet 1925; Hampson 2022). Meanwhile, the call in tomb of Ibi (PM IV, 243-244) mentions the type of metal to be worked *skr d<sup>c</sup>m ir(i) m spr*, ‘Beat electrum, make (it) a foil/a sheet metal!’ (Erman et al. 1919; Drenkhahn 1976; Montet 1925). It can only be presumed if *spr* (*Wb* IV) as opposed to *p3kt* indicates the probably more precious electrum foil. The answer to the call in the tomb of Ibi (PM IV, 243-244) confirms the final result of the work *i.e.* that the work has been completed as desired: *wnn nfr*

‘It becomes beautiful’ (Erman et al. 1919).

In the tomb of Wepemnefret (PM 281-282), there is a dialogue starting with *psi nn iw wsr b3z s3p pw*, ‘Anneal this, it is hard, it is light (colored) metal!’ (*Wb* I; Jungst 1982), and the answer was *n wnt 3d pst.f mnh*. Scheel interpreted it, even if with some reserve, as: ‘There is no hollow (?), when its annealing is excellent!’ (Scheel 1985). The challenge with this sentence lies in the fact that the word *Sd* is not clear. The expression becomes clear when connected with experimental archaeology concepts. It is known that during the hammering phase, metal hardens after a certain amount of work. “Hard” refers to the disturbance of metal particles – the smallest units of metallic elements, which can include single atoms – across the surface. These disturbances can eventually be removed with further strikes. However, excessive hammering may cause the metal foil to break. Workers were particularly aware of this risk due to the formation of “bubbles” or “fractures.” This issue can be mitigated by properly annealing the worked piece (Weinstein 1974: 23-25). When a worker responds affirmatively to a colleague’s call, the term “*3d*” can likely be translated in this context as “Hollow” (referring to an air bubble). Its determinative may also suggest a “Hole” or “Hollow space” (Meeks 1977). Similarly, in the tomb of Ty (D22, PM III, 468-478), the texts reads: *di spr pw r fsi iw.f tw3(w)*. The translation of *tw3* is problematic (Erman et al. 1919), Montet and Jungst (Montet 1925; Jungst 1985) interpreted *tw3* as ‘hard’. Meanwhile, Scheel translated the term as ‘hard,’ similar to the word *wsr* in the inscription from the tomb of Wepemnefret (PM 281-82). He noted that *wsr* (‘dry, withered’) is a synonym for ‘hard’ (Scheel 1985). Additionally, *tw3*, meaning ‘raise, lift, elevate’ (*Wb*, V), serves as a way to express the hardened state of the metal. Another interpretation is given by Scheel.

When the metal foil becomes hot it can be uniformly being hammered until it becomes flat. But when it cools down, it shouldn't be hammered. As a result, it becomes wavy, curvy, and the foil must be annealed again in order to be easily hammered. The expression *i(w).f tw3(w)* explain perfectly this very state. Scheel suggests translating it 'it is curved' (Scheel 1985). Therefore, the accompanying text of the hammering scene in the tomb of Ty (D22, PM III, 468-78), reads: *dī spr pw r fsi iw.f tw3(w)*, 'Give (bring) this foil to the annealing, it is curved!'. In the tomb of Niankhkhnum and Khnumhotep (PM III, 641-44), the accompanying text reads: *h3(i) nw hr sprwi sh wnw h̄c hmww*, that Scheel translates: 'This falls for (both) foils, the beating is present around the workers'(?)' (Scheel 1985). The inscription is clearly related to the hammering stones held by the workers in their hands. With very high blows directed on the foil the metal is flattened by the hammering stones. The tomb of Niankhkhnum and Khnumhotep (PM III, 641-44) expresses the hammering by a scene caption. It reads: *srd m hr*, 'Hammering to the lower side' (Drenkhahn 1976); 'Beating the underside' (Hampson 2022).

## 5. The vase manufacture, polishing, gilding, and secondary activities

### 5.1. Vase manufacture

In the metalworking scenes, texts related to the manufacture and polishing of vases appear sporadically. An example of an accompanying text can be found in the causeway of Unis, but this limited evidence prevents any definitive conclusions. One scene depicts a metalworker engaged with the pouring spout of a washing vase, accompanied by the text "*wdi(dw) sh3t*", which translates to "Fastening of the (spout of the vase) *sh3t*". Likely, *sh3t* refers specifically to the pouring spout itself. The

second text related to vase manufacture appearing on the Unis causeway is also unclear. It reads: *tpi n d̄m*, 'Making-*tpi* – the utensil for washing hands – in electrum'.

### 5.2. Vases polishing

Concerning vases polishing, there is one representation in Unis causeway that describes it as *sint*, 'Polishing' (*Wb*, IV).

### 5.3. Metal gilding

The accompanying texts of gilding are attested in the tomb of Niankhkhnum and Khnumhotep (PM III, 641-44). The activity of gilding is expressed by the verb *s̄sr*: (*Wb*, IV; Drenkhahn 1976). According to Jungst (1985), it is best translated as 'Wrapping', since a 'Coating' of wooden objects with liquid gold is not possible. It is more probable that the objects to be gilded were 'Wrapped' with a thin gold foil or with a gold leaf.

### 5.4. Secondary activities (not directly related to metalworking)

There are two scene captions in the tomb of Ibi (PM IV, 243-44) that describe the manufacture of beads. The first inscription reads: *sn̄c̄ hrst in ms-n̄ddw*, 'Polishing of the beads by the workers of ornamental stones' (Montet 1925). The second inscription reads: *wb3 hrst ms-n̄šdw*, 'Drilling a hole in the beads by the workers of ornamental stones'; 'Drilling the carnelian by the jewelry makers' (Hampson 2022).

## 6. Discussion

During the Old Kingdom, the metalworking scenes accompanying texts represented 13.91% of the total available sub-themes' texts (115 texts) attested in elite tombs. This percentage is based on MastaBase. When analyzing statistical data, it is crucial to recognize that such data is subject

to change. Statistical data provides valuable insights based on current trends, patterns, and observations of the accompanying texts. However, its dynamic nature means that it evolves over time as new information becomes available and as conditions shift. This fluidity can impact the interpretation and relevance of the data, making it essential for any analysis to consider the temporal context and potential for change. The currently available data is expected to change in the following years, upon the discovery of new tombs. Metalworking scenes should be understood within the broader context of tomb decoration, as part of the “scenes of seeing”. In these depictions, the tomb owner is shown standing or sitting, observing craftwork performed on his behalf. The scenes primarily depict the production and use of objects within the economy of delayed return. While most items produced were part of burial equipment, they may also have been used in daily life. Notably, Old Kingdom metalworking tomb scenes depict the creation of metal sheets for crafting prestige vessels rather than the casting of metal tools for tomb construction. Workshop scenes in tombs likely symbolize the role of the work in sustaining the *k3* of the deceased, portraying tasks performed for the tomb owner in life as continuing in the afterlife. While none of the metalworking depictions are identical, they share consistent elements. All scenes show blowpipes directed at the front of the crucible to ventilate the fire above the metal charge, not beneath it, with two or three operators involved. Some scenes also depict crucibles being carried and molten metal poured from knee height onto a flat surface, where it was hammered into sheets. The most detailed metalworking scenes are found in the tombs of high officials, such as Ty of Saqqara, whose proximity to the king likely secured access to the best craftsmen. Tombs in central locations

like Giza, Memphis, and Abusir feature the most elaborate reliefs and captions, a style that extended into the 5<sup>th</sup>-6<sup>th</sup> dynasties and influenced tombs in Meir and Deir el-Gebrawi. In contrast, tombs further south contain more minimal and descriptive captions. While these scenes offer valuable insights, many remain insufficiently published (Motte 2021: 309). In the meantime, the accompanying texts of the metalworking scenes from the Old Kingdom provide a vivid and near-authentic portrayal of workshop activities. These texts not only depict the processes and techniques employed but also offer a dynamic glimpse into the daily life of metalworkers. The frequent and sometimes peculiar captions – featuring calls, dialogues, and responses between workers and overseers – shed light on the interpersonal interactions and daily routines within the workshops. Such detailed inscriptions not only document the material culture but also reflect the evolving practices and social dynamics of the time. Analytically, the captions of each specific scene can be categorized according to their content as follows:

- the scene caption, which provides a brief title or description of the activity depicted in the wall paintings.
- the title or profession of each metalworker involved in the scene, identifying their roles and responsibilities.
- the remarks, exclamations, or dialogues expressed by the metalworkers as portrayed in the scene.
- the responses or exclamations from colleagues and overseers are detailed, reflecting the interactions and dynamics within the workshop.

This structured approach allows for a comprehensive analysis of the textual and visual elements of the metalworking scenes, facilitating a deeper understanding of the depicted activities and interactions. This subdivision aims to facilitate the distinction of the inscriptions of all

the attested sources with respect to each of the specific activities of metalworkers. For example, working instructions as well as dialogues were expressed, in addition to the complaints of the hard work, the request for beer in order to get some refreshment in the difficult conditions, such as the high temperature and the smoke caused by melting. Such inscriptions reflect a social and real life during the metalworking activities. It is observed that technical details were most frequently conveyed in the form of commands. For instance, commands recorded in the tombs of Wepemnefret (PM III, 282 [6]), Ty (D22; III, 473-4 [36]) such as *psi nm biz* '(Re)heat this metal!' and *di spr pw r fsi* 'Let this sheet reheat!', appear to describe the annealing process, in which metal is repeatedly heated and cooled to enhance its ductility. Although the inscriptions inherently contain a range of technical jargon, the existence of a coherent metalworking jargon cannot be readily assumed. The grammar and specific modes of expression – aside from the technical terms unique to each field – show no significant differences when compared to other textual genres. It is noteworthy that certain forms are preferred, such as the imperative used in calls and the infinitive in scene captions. From a linguistic perspective, the imperative and the initial subjunctive form *sdm.f* are the most commonly used. The imperative serves as the standard method for commanding someone to take action. This preference is also observable in other specialized jargons within the Egyptian language (Motte 2021: 307). To conclude, this paper has shed light on the relationship between text and image. The key finding is that an object's identification is determined by its common attributes rather than the context in which it is depicted. Decorative programs in tombs highlight the owner's elite status for both contemporaries and future generations.

Motte identifies seven recurring themes with speech captions from the Old Kingdom to the Late Period: agriculture, animal husbandry, butchery, crafts, dance and music, food preparation, and hunting. These scenes often depict ongoing or anticipated actions, where the imagery and text work together, with the visuals serving as determinatives and sometimes substituting for first-person pronouns (Motte 2021: 303). The use of a general term for metals, *biz*, highlights that the defining feature of each designation, regardless of its specific use, is the shared characteristic of the raw material. The copper production process involves four main stages: ore procurement and transport, copper storage and transactions, melting and object production, and the use and reuse of artifacts. This analysis explored the role of scene inscriptions in shaping the physical and social context of ancient Egyptian craftsmen, as well as their contribution to the overall thematic presentation. Generally, the titulary of metalworkers indicates a low rank, as they could only afford smaller tombs, reflecting their relatively modest social status among Memphite officials. The texts can be categorized into several sub-groups, serving either descriptive or explanatory purposes. Notably, certain categories, especially those presented as conversations or commands, also provide insights into the workshop's organization and practices, offering additional context to the viewer. For example, the social distinction between workers and their superiors is evident in the titles used in both calls and responses. Workers of equal status address each other as *nt(i) hm'.(i)*, "My comrade" or "mate." In contrast, the overseer is referred to as *iti*, 'meaning "Prince"/ "Patron"/ "Chief". The overseer issues commands using the imperative form and addresses subordinates directly with "You." The overseers were called 'chief' *iti*, a term etymologically derived from *it*, meaning father. This

designation may have been metaphorical, but it often also reflected a real sense, as the craft was passed down through generations of artisans (Odler 2023). Furthermore, the social position of specific groups of workers can be determined by titles and profession names. For example, in the representations of weighing the crude metal and metallic objects, the person in charge appears with the title of scribe, or director of metalworkers or officers with high-ranking titles. When the title is missing, the social position can be established easily in the iconography, for example the man who is busy with the weighing in the tomb of Senedjemib (PM III, 87-89), wears a wide, lightly projecting kilt which clearly denotes him as an overseer. In the tomb of Kaemrehu (D 2, PM III, 485-87) the overseer is distinguished as a member of the administration with respect to the 'Ordinary' worker through his writing instruments, reed pen and palette. No melter bears a title indicating membership in a higher social class. The clothing of melters consists of a simple, short leather kilt typical of a laborer, or at times, just a loincloth.<sup>22</sup> Melters, who often represent the majority of the workforce in metalworking scenes, clearly belong to the lowest social class, below the metal smiths. Unlike the hammerers or the coarsely or finely-working smiths, no specific manual expertise is expected of the melters, nor do they possess the higher education associated with scribes. It is likely that they were selected for their strength and endurance to perform this hard and unpleasant work. Consequently, it is not surprising that melters often urged one another to work through calls, while also expressing

their complaints about the physical demands of their labor to their overseer and loudly requesting beer for refreshment. Similar to the metalworking activities on wall scenes, the metalworking process and crucible shape were reflected in three-dimensional art. A statue of a man melting metal in a crucible is preserved in ISAC (E10631).<sup>23</sup> It is carved in fine limestone and painted. The man holds a blowpipe in his hands which extends from his lips to the open side of a crucible. His cheeks are puffed out to indicate that he is in the act of blowing air into the blowpipe (Davey 2009: 37-46). On the same social level as the melters were the pourers, who likely lacked specialized manual skills, as pouring molten metal is often considered a dirty job in forges. There are no titles associated with their work, and their clothing is similar to that of the melters. The gilders appear to belong, on the contrary, to a higher level among the group of metalworkers. The title of 'Overseer of metalworkers' is attested several times among the hammerers. The hammering required, contrary to melting and pouring, more specific knowledge on the characteristics of the different types of metal like silver, electrum, gold and copper.<sup>24</sup> In ancient Egypt, royal expeditions were sent to mine precious metals and quarry valuable stones. The kings of ancient Egypt commissioned mining expeditions to Sinai to extract copper and turquoise (Mansour 2014). After obtaining copper as a raw material, it was melted on-site to produce ox-hide ingots, which facilitated transport to royal metallurgy workshops in the Nile Valley for use in various products. Recent discoveries by the Egyptian mission

<sup>22</sup>Servant statue, ISAC (E10631) depicting one of these workmen.

<sup>23</sup>The Institute for the Study of Ancient Cultures is the new name of Chicago Oriental Institute. Height 110 mm, length 100 mm, width 50 mm.

<sup>24</sup>Copper main production areas in ancient Egypt are: the eastern desert, Sinai in both Serabit el-Khadim and Wadi Nasab and Tell el-Dab'a. See Abdel-Motelib et al. 2012; Rademakers et al. 2021; Verly et al. 2022.

support this view (Mansour 2024: 87-101).<sup>25</sup> Although the hammerer belongs to the group of hardworking smiths, had to be able, for example, to decide if a metal piece needed to be annealed again in order to avoid severe damage to the metal foil while hammering it. The specialization of work among the hammerers on specific metals can be brought back to the different reaction of the several types of metal during hammering and other working techniques. As mentioned above in Unis Causeway and in the tomb of Mehu (G 2423, PM III, 94), all the metals were worked by a “Metalworker”. Starting from the 6<sup>th</sup> Dynasty (or later) gold was hammered by a ‘Goldsmith’. A clear social structure can be observed in the metalworking activities of the Old Kingdom, as evidenced by both the accompanying texts and the iconography. In this hierarchy, gilders and hammerers hold the highest positions as “hard and soft working smiths”, followed by polishers. At the lowest level are the melters and pourers. The weighmen of crude metal and finished metallic objects represent an exception; while their role involves weighing, it is not strictly part of metalworking but rather an administrative procedure. Consequently, scribes and officers are categorized within the administrative personnel. Another key feature metalworking accompanying texts, besides the limited space for inscriptions – usually no more than two or three sentences – is the size of the hieroglyphs. The hieroglyphs in the speech captions are smaller to distinguish the common workers from the tomb-owner, who is depicted with larger hieroglyphs. This smaller size acts as

a form of separation, much like the use of quotation marks. The accompanying texts, often considered representations of vernacular speech, are actually formalized texts found in private tombs. According to P. Vernus, these texts mimic the phrasing of autobiographies from the Old Kingdom and Late Period tombs, serving as stylized imitations of colloquial language rather than authentic examples.

## Bibliography

- Abdel-Motelib, A., Bode, M., Hartmann, R., Hartung, U., Hauptmann, A. and Pfeiffer, K. 2012 Archaeometallurgical Expeditions to the Sinai Peninsula and the Eastern Desert of Egypt (2006-2008), *Metalla* 19.1/2: 3-59.
- Altenmüller, H. 1984 Sokar im Alten Reich und der Wind, *Göttingen Miszellen* 78: 7-17.
- 1986 Zum Abwiegen von Metall im Alten Reich und zur Redenwendung “iw.s m jnr”, *Göttingen Miszellen* 89: 7-14.
- Chen, L.B., 2021 Sumerian Arsenic Copper and Tin Bronze Metallurgy (5300-1500 BC): The Archaeological and Cuneiform Textual Evidence, *Archaeological Discovery* 9: 185-97. doi: <https://doi.org/10.4236/ad.2021.93010>
- Curto, S. 1962 Postille circa la Metallurgia Antico-Egizia, *Mitteilungen Des Deutschen Archäologischen Instituts Abteilung Kairo* 18: 59-69.
- Davey, Ch. 2009 ‘A Metalworking Servant Statue from the Oriental Institute, University of Chicago’, *The Bulletin of the Australian Centre for Egyptology* 20: 37-46.

<sup>25</sup> Moreover, in his recent book, Odler analyzed the discovered in different archaeological sites in Egypt, such as the predynastic ingots from Maadi, Saqqara, Bet Khallaf, southern limit of Royal cemetery at Abusir, and Tell el-Daba. He reported that the ingots were made of arsenical copper. The general shape of the ingots is: flat ingots, bowl-shaped ingots, disc-shaped ingots, and plano-convex ingots as well (Odler 2023).

- 2011 Discovering Old Kingdom Metallurgy, *WAMCAES News Issue* 8: 25-36.
- Davey, Ch. J. and Hayes, P.  
2023 Of the Fiery Crucible: Egyptian Old Kingdom metallurgy, *Buried History* 59: 11-28.
- Drenkhahn, R.  
1976 *Handwerker und ihre Tätigkeiten im Alten Ägypten* (Ägyptologische Abhandlungen 31), Wiesbaden.
- Edel, E.,  
1955 *Ägyptische Grammatik* (Analecta Orientalia 34/39), Rome.
- Erman, A.  
1919 *Rufe und Lieder auf Gräberbildern des Alten Reiches* (Abhandlungen der Preussischen Akademie der Wissenschaften 15), Berlin.
- Forbes, R.J.,  
1972 *Studies in Ancient Technology IX*, Leiden.
- Grapow, H.  
1960 *Wie die Alten Agypter sich anredeten, wie sie sich grübten und wie sie miteinander sprachen*, (Deutsche Akademie der Wissenschaften zu Berlin 26), Berlin.
- Hampson, M.  
2022 *'Make it According to Plan.' Workshop Scenes in Egyptian tombs of the Old Kingdom*, Oxford.
- Helck, W.  
1971 *Das Bier bei den alten Agyptern*, Berlin.
- Hodjash, S. and Berlev, O.  
1982 *The Egyptian Reliefs and Stelae in the Pushkin Museum of Fine Arts, Moscow*, Leningrad.
- Jungst, H.  
1982 Zur Interpretation einiger Metallarbeiterszenen auf Wandbildern altägyptischer Gräber, *Göttinger Miszellen* 59: 15-27.
- Kanawati, N. Evans, L.  
2014 *Cemetery of Meir Vol. II. The Tomb of Pepyankh the Black* (The Australian Center for Egyptology: Reports 34), Oxford.
- Kuhlmann, K.P.  
1976 „Gewicht“ und die Redewendung jw.f m jnr „im Gewicht sein“, *Göttinger Miszellen* 22: 39-41.
- Mansour, A.  
2014 *Turquoise in Ancient Egypt, Concept and Role*, Oxford.
- 2024 A Probable Production of Ox-hide Ingots during the Middle Kingdom in Ancient Egypt: Iconographical Perspective, in T. De Putter and C. Karlshausen (eds), *Minerals in Ancient Egypt, from Naqada to Alexandria. Proceedings Royal Academy for Overseas Sciences* (International Conference, Brussels, 3-4 October 2022), Uccle: 87-101.
- Meeks, D.  
1977 *Année lexicographique I*, Paris.
- Montet, P.  
1925 *Scènes de la vie privée dans les tombeaux Égyptiens de l'ancien empire*, Strasbourg.
- Motte, A.  
2021 Reden und Rufe, a Neglected Genre? Towards a Definition of the Speech Captions in Private Tombs, *Bulletin de l'Institut Français d'Archéologie Orientale* 117: 293-317.
- Moussa, A.M. and Altenmüller, H.  
1977 *Das Grab des Nianchnum und Chnum-hotep. Old Kingdom Tombs at the Causeway of King Unas at Saqqara* (Archäologisches Veröffentlichungen 21), Mainz am Rhein.
- 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 132), Leiden.
- Piacentini, P.  
2002 *Les scribes dans la société égyptienne de l'Ancien Empire, Vol. I: Les premières dynasties Les nécropoles memphites* (Études et Mémoires d'Égyptologie No. 5), Paris.
- Rademakers, F.W., Verly, G., Delvaux, L. Vanhaecke, F. and Degryse, P.  
2021 From Desert Ores to Middle Kingdom Copper: Elemental and Lead Isotope Data from the RMAH Collection, Belgium, *Archaeological and Anthropological Sciences* 13: 100. doi: <https://doi.org/10.1007/s12520-021-01329-w>

- Roccati, A.  
1982 *La littérature historique sous l'ancien empire égyptien*, Paris.
- Scheel, B.  
1985 *Studien zum Metallhandwerk im Alten Ägypten I: Handlungen und Beischriften in den Bildprogrammen der Gräber des Alten Reiches* (Studien zur Altägyptischen Kultur 12), Hamburg: 117-177.  
1986 *Studien zum Metallhandwerk im Alten Ägypten II: Handlungen und Beischriften in den Bildprogrammen der Gräber des Mittleren Reiches* (Studien zur Altägyptischen Kultur 12), Hamburg: 181-205.
- Verly, G. Verly, Téreygeol, F. and Rademakers, F.W.  
2022 Minerais arséniés et production d'alliages de cuivre, in F. Téreygeol (ed.), *PCR. Archéologie expérimentale des matériaux associés aux productions métalliques: (Re)mettre la science en culture. Rapport intermédiaire 2022*, Gif-sur-Yvette: 19-40.
- Weinstein, J.M.  
1974 A Fifth Dynasty Reference to Annealing, *Journal of the American Research Center in Egypt* 11: 23-25. doi: <https://doi.org/10.2307/40000770>

